Great Lakes Inventory and Monitoring Network
Phase III Report

Long-Term Ecological Monitoring Plan

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Great Lakes Inventory and Monitoring Network
Ashland, Wisconsin 54806

"In our every deliberation, we must consider the impact of our decisions on the next seven generations."

From the Great Law of the Iroquois Confederation

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Executive Summary

This Phase III Report documents the background, purpose, and overall strategy for conducting a long-term ecological monitoring program for nine National Park Service (NPS) units in the western Great Lakes region of the United States. The proper planning of such an extensive program requires a major investment of time and funds to gather and synthesize background information and prioritize future monitoring needs. Hence, numerous background reports and documents were produced during the planning of this monitoring program. This document summarizes those efforts and provides the framework within which the monitoring program will be conducted. More detailed planning and background information can be found in supplemental documents and technical reports, which are referred to throughout this plan and are listed in Appendix A.

The NPS has organized 32 'networks' of parks across the nation. Each network consists of several NPS units (parks) with similar ecology, geography, and management issues. This plan covers the Great Lakes Network (GLKN), which includes the following parks: Apostle Islands National Lakeshore, Grand Portage National Monument, Indiana Dunes National Lakeshore, Isle Royale National Park, Mississippi National River and Recreation Area, Pictured Rocks National Lakeshore, Sleeping Bear Dunes National Lakeshore, St. Croix National Scenic Riverway, and Voyageurs National Park.

The purpose of the monitoring program is to provide park managers with status and trends data on select indicators that represent the health of natural resources in the nine parks. These indicators are termed "Vital Signs" and they will be monitored long-term under a set of protocols that provide detailed guidance on the methods, schedules, analytical tools, and reporting procedures.

Parks in the Great Lakes Network range in size from Grand Portage National Monument at 287 ha (710 acres) to Isle Royale National Park, which is 231,396 ha (571,790 acres) in size. Six of the units are located on one of the Great Lakes, two are on large river systems, and one includes portions of the U.S. and Canadian border lake complex with a mosaic of freshwater lakes, ponds, and streams. Together, these parks represent the major freshwater ecosystems of the region; as such, freshwater is one of the defining elements of the Network. Yet the terrestrial systems are equally important. Vegetation of the northern parks is characterized as boreal forest with conifer lowlands and mixed deciduous and coniferous uplands with interconnected lakes, ponds, and waterways. Parks in the southern portion of the region are dominated by broadleaf forests, which harbor greater native plant and animal diversity than the northern forests. These southern areas are also more impacted by human development including large cities and transportation corridors. Climate in the region is mid-continental with mean annual precipitation ranging from 64.5 to 90.7 cm (25.4 to 35.7 in), and temperatures that vary from minus 40 ˚C (-40 ˚F) in winter to over 32 ˚C (90 ˚F) in summer. Due to lake effects near the Great Lakes, annual snowfall ranges widely from 71.1 to 342.6 cm (28 to 135 in).

To understand park ecosystems and to help select appropriate indicators to monitor, the Network commissioned the development of six conceptual models that represent the primary ecosystems of the nine parks. The six models are: Upper Great Lakes Earth Processes, Great Lakes Forests, Great Lakes Wetlands, Inland Lakes, Large Rivers, and Great Lakes. Each model consists of a narrative and diagram(s), which summarize the major ecosystem drivers and stressors and identify important linkages, and possible measures. In each of the modeling efforts, climate and human development were identified as major agents of change. These agents of change cause ecological stress including extreme weather, resource extraction, pollution, and habitat fragmentation. The resulting effects include ecosystem contamination, changes in the distribution and abundance of native and exotic species, and altered soils and hydrology.

Through modeling efforts and meetings with park and partner scientists, the Network identified and prioritized 46 Vital Signs important for monitoring in the nine parks. This list of 46 was refined to a short list of 21 Vital Signs for which the Network expects to be able to design and implement monitoring protocols over the initial six years (2006 – 2011). Some of the remaining Vital Signs will be monitored by the individual parks, some are being monitored by partners, and still others will go unmonitored unless additional funding is made available. The 21 Vital Signs for which the Great Lakes Network intends to develop protocols in the first six years are:

- Air Quality
- Weather
- Land Cover/Use Coarse Scale
- Land Cover/Use Fine Scale
- Aquatic /Wetland Plant Communities
- Amphibians and Reptiles (Amphibians)
- Stream Dynamics
- Diatom Community
- Trophic Bioaccumulation
- Terrestrial Plants
- Succession
- Terrestrial Pests and Pathogens
- Soils
- Plant and Animal Exotics
- Problem Species (White-tailed Deer)
- Bird Communities
- Fish Communities
- Water Level and Flow
- Species Health, Growth and Reproductive Success
- Core Water Quality Suite (pH, specific conductance, dissolved oxygen, temperature)
- Advanced Water Quality Suite (nutrients, biotic indicators, and other factors)

The Network expects to monitor these 21 Vital Signs through the consistent application of 16 scientifically defensible protocols. The development of protocols will occur over the first six years with a push to implement 10 separate protocols covering 17 Vital Signs in the first two years (2006 and 2007). However, protocol development and the extent to which each Vital Sign is monitored depend on cost and future funding.

In 2006, we began field work for four monitoring protocols: water quality for large rivers, water quality for inland lakes, amphibians, and bioaccumulative contaminants. In 2007 we will strive to add five additional protocols: climate/weather, terrestrial vegetation, both coarse and fine scale land cover/ land use, and landbirds. Whether we meet our goal of implementing 10 protocols in the first two years will depend on hiring additional staff and the success of national efforts (e.g. climate/weather is being developed in-part by the nation inventory and monitoring program).

The Great Lakes Network will expend about 36% of its fiscal resources on data management. The data that results from this monitoring program will be subjected to quality assurance/ quality control procedures and formal archival processes that are spelled out in a data management plan and in specific standard operating procedures for each protocol.

Data resulting from the Great Lakes Network monitoring efforts will be presented at an annual conference and meeting of park scientists and will be made available annually in summary reports. On a less frequent basis, the Network will analyze, interpret, and synthesize the data. The frequency with which analysis and synthesis reports are produced will depend on the Vital Sign and how often it is monitored. Where appropriate, the results will be submitted for publication in peer reviewed literature and/or presented at science conferences.

The Network's website (www.nature.nps.gov/im/units/glkn/index.htm) will be the primary means of making data and reports available. The website will be updated regularly to provide access to reports and raw data. A section of the Network's website, which is still under development, will be map-based using an Internet Mapping Service (IMS) to provide access to spatially explicit data and allow users to explore Network data in a spatial context. The Network's website will allow users to query and download data for use on local computers.

The Great Lakes Network has a central office in Ashland, Wisconsin with professional staff to coordinate and carry out the program. Natural resource staff and superintendents from each of the nine parks make recommendations and decisions on program direction and implementation through a Technical Committee and a Board of Directors. Oversight and guidance is provided by a Servicewide Inventory and Monitoring (I&M) Program and through the Midwest Regional Office (MWRO).

Chapter 1 – Background Information

INTRODUCTION

The National Park Service (NPS) has instituted a program to inventory and monitor natural resources in approximately 270 park units across the nation. The program is being implemented by forming 32 'networks' of parks that share common management concerns and geography. By funding these networks, the NPS hopes to minimize redundancy, maximize cost effectiveness, and increase consistency in data collection and information transfer.

The Great Lakes Inventory and Monitoring Network (hereafter, GLKN or the Network; see Appendix B for a list of acronyms) is composed of nine national park units in Minnesota, Wisconsin, Michigan, and Indiana (Figure 1.1). The Network was formed in 1999 and began implementing a biological inventory program in 2000 (Route 2000). The Network's biological inventory program is designed to gather baseline information on vertebrates and vascular plants in the nine parks, including cataloging existing information and implementing field inventories to fill critical knowledge gaps. Simultaneously, other programs within the NPS are gathering and summarizing information on air and water resources; developing state-of-the-art maps of vegetation, soils, and geology; and designing web-based data systems for easy access to information throughout the NPS. These efforts were made possible by one of the largest increases in funding and staffing for natural resource management in the history of the NPS.

The Network received funding in 2002 to begin planning its **Vital Signs** monitoring program. (Words and phrases that are bolded within the text can be found in the glossary, Appendix C.) Herein we describe the purpose and goals of the monitoring program, the prioritized list of what the Network intends to monitor, and how we intend to carry out such monitoring over the next six years.

Developing an ecological monitoring program requires an initial investment in planning and design to ensure that critical information needs are met and that results are clearly understood and readily available. Each network is required to design a monitoring program that addresses the Servicewide goals, yet is flexible enough to meet local ecological and managerial needs. To determine appropriate strategies and **indicators**, all networks are expected to take a phased approach to planning that incorporates five steps that are reported in this Phase III Report:

In Phase 1:

1. Catalog and summarize existing data and knowledge of park **ecosystems**.
2. Develop conceptual models of relevant ecosystem components.

In Phase 2:

3. Develop specific monitoring objectives and select indicators.

In Phase 3:

4. Determine the appropriate sampling design and sampling protocols.
5. Implement data management, analysis, and reporting procedures.

Figure 1.1. Location of the nine National Park Service units that comprise the Great Lakes Inventory and Monitoring Network. Land cover background is from the National Land Cover Dataset by the U.S. Geological Survey (from Landsat imagery circa 1990). Dark green is evergreen forest while lighter greens are mixed and deciduous forest. Yellows and orange show agricultural crop lands, pasture, meadow, and other open grasslands. Red and pink identify urban centers and residential areas respectively.

Table 1.1 shows the timeline and progress of the Great Lakes Network in the completion of the three-phased process. Throughout this process GLKN gave equal consideration to air, geologic, terrestrial, and aquatic systems in the nine parks. The only preconceived Vital Signs were core water quality indicators required by the NPS Water Resources Division (WRD) including pH, specific conductance, dissolved oxygen, temperature, and flow/water level in those waterbodies being monitored.

In Phase 3 we began integrating our monitoring with current park- and partner-funded efforts. This integration involved a blend of strategies including: 1) incorporating data from ongoing park and partner monitoring, 2) augmenting park-based monitoring, 3) commissioning partners to conduct monitoring, and 4) having Network teams conduct monitoring. Regardless of who collects the data, for all Network-initiated monitoring programs the Network will be responsible for design, quality control, data archival, analysis, and reporting.

Table 1.1. Timeline for the Great Lakes Inventory and Monitoring Network to complete the 3-phase process of planning and designing a long-term ecological monitoring program. An Inventory and Monitoring Advisory Committee (IMAC) of national, regional, Network, and park staff determines deadlines for major steps and reports.

Planning and design step	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006
Gather information and catalog data	X	X	X	X	X	X	
Conduct inventories to support monitoring		X	X	X	X	X	
Hold park scoping workshops		X	X				
Develop conceptual models			X	X			
Prioritize and select indicators					X		
Develop protocols and monitoring designs					X	X	X
Implement initial monitoring							X
Monitoring plan due dates Phase reports 1, 2, 3					Phase 1 Oct. 03	Phase 2 Oct. 04	Phase 3 Dec. 05

Purpose of Long Term Ecological Monitoring in National Parks

National park managers are mandated to understand, maintain, restore, and protect the integrity of natural resources (e.g., air, water, soils, native plants, and animals), processes (e.g., erosion, succession, fire, and bioaccumulation of toxics), and values (e.g., scenic views and solitude) within their boundaries (NPS 2001). Yet managers are confronted with increasingly complex and challenging issues that require an understanding of the status and trends of park resources.

A long-term approach to natural resource monitoring is needed because short-term studies cannot adequately represent cyclic phenomena, often miss significant transitory events, cannot adequately track incremental changes in resources, and are less able to detect change when there is a lag in the ecosystem response (Frederick and Ogden 2003). Furthermore, long-term studies of interannual variability have greater statistical **power** than do shorter-duration studies, and are better able to test associations of changes in resources with anthropogenic and natural factors (Larsen et al. 2001). Long-term monitoring data can also help define the normal ranges of natural variation in park resources and can provide context in which to analyze data from research. Such long-term monitoring must occur at multiple scales (both resolutions and extents) because no single temporal or spatial scale is adequate for all system components and processes. For example, the appropriate level for understanding and effectively managing a resource might be genetic, population, species, community, or landscape (Noss 1990). In some cases, effective management may require a regional, national, or international effort. National parks are part of larger ecosystems and must be managed in that context. Understanding the dynamics of park ecosystems and the consequences of human activities is essential for making decisions to maintain, enhance, or restore the **ecological integrity** of park ecosystems (Roman and Barrett 1999).

Legislation, Policy, and Guidance

National park managers are directed by federal law and NPS policies and guidance to know the status and trends of natural resources under their stewardship, as stated in the mission of the National Park Service: "*...to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*" (National Park Service Organic Act 1916).

More recently, the National Parks Omnibus Management Act of 1998 established the framework for integrating natural resource monitoring into park management. Section 5934 requires the Secretary of the Interior to develop a program of "*inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources*."

Congress reinforced this message in its FY 2000 Appropriations bill: "*The Committee applauds the Service for recognizing that the preservation of the diverse natural elements…involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."*

The 2001 NPS Management Policies (NPS 2001) specifically directed that: *"Natural systems in the National Park System, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and* *research to understand the detected change and to develop appropriate management actions."*

Further, *"The Service will:*

- Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents.
- Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship and identify the processes that influence those resources.
- Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals.
- Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames.
- Use the resulting information to maintain and, where necessary, restore the integrity of natural systems" (NPS 2001).

Several other important statutes, such as the Clean Water Act and the Endangered Species Act, provide legal direction for determining the condition of natural resources in parks. For a description of the legislation and policy directives relevant to the monitoring program see Appendix A, Supplemental Document 1 and on-line at: http://science.nature.nps.gov/im/monitor/LawsPolicy.htm.

Goals for Vital Signs Monitoring

The purpose of this program is to identify and monitor Vital Signs of park ecosystems. A Vital Sign may be a physical, biological, chemical element or process that: indicates the health of a park ecosystem, responds to natural or anthropogenic stresses in a predictable or hypothesized manner, or has high value to the park or the public (e.g., endangered species, charismatic species, exotic species). The NPS Vital Signs program is intended to monitor key elements of park ecosystems to help detect ecological problems that need further research or management action.

Specifically, Servicewide goals for Vital Signs monitoring (Fancy 2004) are to:

- "Determine status and trends of selected indicators of the condition of park ecosystems to help managers make better-informed decisions and work more effectively with other agencies and individuals for the benefit of park resources.
- Provide early warning of abnormal conditions and impairment of selected resources to promote effective mitigation and reduce management costs.
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other altered environments.
- Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.

- Provide a means of measuring progress towards achieving performance goals that are mandated by Government Performance Results Act (GPRA)".

The Great Lakes Network adopts these Servicewide goals and further defines the intentions and limitations of the Network's program with the following provisions:

1. The majority of the Network's funding and efforts will be directed at monitoring trends in resource themes or issues that are common across Network parks and that individual parks would find difficult to accomplish due to high cost, magnitude of scale, or lack of expertise. This commonality across parks and monitoring themes will increase staff efficiency and cost-effectiveness, promote sharing of data, and allow comparison of trends across the Network.
2. In cases where Vital Signs are already being monitored by one or more parks, and the Network assumes the cost of monitoring, the park(s) agree(s) to re-allocate park-based funds and staff to other natural resource efforts in that park. Parks will continue to monitor various resources not monitored by the Network, conduct short-term assessments and field studies, and facilitate research.
3. The Network's monitoring program will be designed with quality of information in mind - not number of issues addressed. The objective is to provide high quality data on a core set of resource indicators. Additional research and park-based monitoring can expand from this core set of indicators.
4. The Network will strive for multiple lines of evidence to document significant changes in resource status. Further, we expect that trends in Vital Signs will provide a basis for developing and testing hypotheses for cause-and-effect research. It is the shared responsibility of the Network, each individual park, the Great Lakes Research and Education Center, and our science partners to uncover important trends in Vital Signs and seek funding to conduct research on the causes and effects of such trends.
5. The Network monitoring program will strive for consistency in long-term data collection yet allow for flexibility to alter or remove indicators that are not meeting objectives.

Monitoring objectives

The Great Lakes Network has refined the Servicewide goals into broad monitoring objectives. These objectives are organized below, in Table 1.2, within six major resource categories as identified by the Servicewide Inventory and Monitoring Program as a framework for tracking and examining Vital Signs across the NPS. These objectives were defined by network staff with park review. They are derived from the Servicewide goals and the Vital Signs selection process (see chapter 3) with due consideration for estimated costs and staff requirements. They provide a broad perspective for the GLKN monitoring program. More specific and measurable monitoring objectives and questions are presented in Chapter 5 and within each protocol.

Table 1.2. Broad monitoring objectives for the Great Lakes Network. Objectives are tied to six resource categories that form a framework for tracking Vital Signs across the National Park Service.

Resource category	GLKN monitoring objectives
Air and Climate	1. Monitor weather patterns and climate, which are major drivers of change and will aid in understanding changes in park ecosystems 2. Assess levels of airborne pollutants, particularly those that are out of compliance with state or federal agencies or that bioaccumulate in park biota
Geology and Soils	3. Monitor geological processes that produce localized, but fundamental, change in important park resources such as sandspits and dunes 4. Periodically assess the properties of soils associated with each park's dominant terrestrial vegetation types
Water	5. Monitor the chemical, biological, and physical components of select inland lakes, rivers, and streams 6. Provide advanced warning of the imminent arrival of targeted aquatic nuisance species in park waters
Biological Integrity	7. Monitor indicators of species diversity, productivity, disease, and succession in dominant terrestrial vegetation types in each park 8. Monitor animal species or communities (e.g., birds, fish, amphibians) whose presence/absence or population status helps evaluate the biotic integrity of the park ecosystems
Human Use	9. Monitor indicators of land use and population growth in areas immediately adjacent to each park to assess the potential relationship between changes observed within and outside of park boundaries 10. Monitor indicators of human use impacts within each park such as water quality
Ecosystem Pattern and Process	11. Monitor changes in land cover and use in and adjacent to each park 12. Monitor ecosystem processes that indicate change or that may aid in understanding changes in other Vital Signs

Performance Management Goals

In accordance with the Government Performance Results Act (GPRA), the NPS must develop 'performance management goals' (GPRA goals) and report on progress towards meeting them. The National Inventory and Monitoring (I&M) Program can help parks attain seven of these goals (Table 1.3). For example, the identification of Vital Signs indicators, goal Ib3, has been accomplished for the nine parks through the efforts of the Network. It may also be appropriate for the Network to monitor certain management actions, such as restoration of disturbed lands, which could help meet other GPRA goals.

Table 1.3. Performance management goals related to inventory and monitoring of parks in the Great Lakes Inventory and Monitoring Network. Class I air quality areas receive the greatest protection, with only small amounts of certain air pollution allowed; 303d-listing designates bodies of water that are out of compliance for particular pollutants; ORW denotes Outstanding Resource Waters.

NPS strategic plan mission goals	Network parks involved
Ia1. Disturbed lands / exotic species – 10.1% of targeted disturbed park lands are restored, and exotic vegetation on 6.3% of targeted acres is contained.	All GLKN parks have invasive exotics and most have disturbed lands, especially INDU, SLBE, and MISS.
Ia2. Threatened and Endangered Species – 14.4% of the 1999 identified park populations of federally listed threatened and endangered species with critical habitat on park lands or requiring NPS recovery actions have improved status, and an additional 20.5% have stable populations.	All nine parks have listed species, but not all have critical habitat and not all species require NPS recovery actions.
Ia3. Air quality – Air quality in 70% of reporting park areas has remained stable or improved.	ISRO and VOYA are Class I air quality areas. ISRO, VOYA, SLBE, and INDU are currently monitoring some aspect of air quality.
Ia4. Water quality – 75% of 288 parks have unimpaired water quality.	303d-listed waters occur in: GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE. ORW occur in: GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE, VOYA.
Ib1. National resource inventories – Acquire or develop 87% of the 2,527 outstanding data sets identified in 1999 of basic natural resource inventories for all parks.	All GLKN parks currently benefit from natural resource inventories; all still need additional natural resource inventories.
Ib3. Vital Signs – 80% of 270 parks with significant natural resources have identified their Vital Signs for natural resource monitoring.	All GLKN parks identified their Vital Signs in 2004.
Ib5. Aquatic resources – NPS will complete an assessment of aquatic resource conditions in 265 parks.	Baseline water quality reports are completed for all GLKN parks, but some are ~20 years old.

BACKGROUND

Ecological Overview of the Region

The Great Lakes I&M Network consists of nine national park units in Minnesota, Wisconsin, Michigan, and Indiana (Table 1.4, Figure 1.1). These parks extend from northern Minnesota to southern Lake Michigan, spanning a distance of more than 1,050 km (650 mi). Four parks are located on Lake Superior, two on Lake Michigan, two on major river systems (Mississippi and St. Croix Rivers), and one is associated with a mosaic of large and small inland waters along the border between Canada and the United States. Thus, fresh water is a prominent natural resource shared by these parks. However, terrestrial resources are equally important because of management concerns stemming from a complex of roads, trails, campsites, and land-based facilities across a diversity of habitat types. The following summary provides an overview of the region and puts the parks into ecological context. For a summary of individual parks refer to Appendix A, Supplemental Document 2 or each park's website at www.nature.nps.gov/im/units/glkn/index.htm.

Table 1.4. Great Lakes Inventory and Monitoring Network parks, with park code, area, and primary water association.

Park	Code	Hectares (Acres)	Primary water association
Grand Portage National Monument	GRPO	287 (710)	Lake Superior
Indiana Dunes National Lakeshore	INDU	6,073 (15,000)	Lake Michigan
Mississippi National River and Recreation Area	MISS	21,772 (53,776)	Mississippi River
Apostle Islands National Lakeshore	APIS	28,086 (69,372)	Lake Superior
Sleeping Bear Dunes National Lakeshore	SLBE	28,821 (71,189)	Lake Michigan
Pictured Rocks National Lakeshore	PIRO	28,906 (71,397)	Lake Superior
Saint Croix National Scenic Riverway	SACN	37,544 (92,735)	St. Croix and Namekagon Rivers
Voyageurs National Park	VOYA	88,281 (218,054)	Border lakes and pond complexes
Isle Royale National Park	ISRO	231,494 (571,790)	Lake Superior
Total		471,264 (1,164,023)	

Cultural History

Network parks share a common history. Over the past three centuries, logging, mining, farming, industrial development, the fur trade, and urbanization have dramatically changed the character and ecology of the areas the parks now protect (Wells 1978, Nute 1931). Fur traders began establishing trading posts in the mid-1600s (Ray 1987). Over the next two centuries, Native American and European trappers removed a staggering number of beaver (*Castor canadensis*) and other furbearers from the region (Schorger 1970).

Large-scale logging began in the 1800s. Most of the lands now within the parks were eventually logged to some degree (Wells 1978, Callison 1967). Dams were constructed in the 1800s and early 1900s to aid the transportation of logs and later used for power generation and navigation at MISS, SACN, and VOYA.

Logging began in the mid-1800s in the more southern and eastern areas, and continued northward until the entire region was cleared of trees by the early 1900s. Intense fires often followed logging and destroyed seed sources and organic matter in the soil. Hunting to supply food for logging camps sharply reduced the number of ungulates and led to extirpation of woodland caribou (*Rangifer tarandus*) and eastern elk (*Cervus elaphus*). Logging created habitat more favorable for white-tailed deer (*Odocoileus virginianus*), and the resulting range expansion of deer has significantly altered forest composition in some areas (Rooney et al. 2004, Blouch 1984). Deer also harbor a parasitic brainworm, *Pneumostrongylus tenuis*, which may limit recovery efforts for moose (*Alces alces*) and woodland caribou (Karns 1967). Mining occurred on some lands that are now protected within parks: brownstone at APIS, clay and gravel at SACN, copper at ISRO, gold at VOYA, and sand and gravel at INDU and SLBE.

Current Human Uses

Water levels continue to be controlled by dams within SACN, MISS, SLBE, and VOYA. These dams affect sediment transport, water temperatures and chemistry, and migration and dispersal of aquatic species. Visitors use parks in the region for a variety of recreational activities, including canoeing, motor boating, kayaking, sailing, fishing, hunting, trapping, camping, swimming, hiking, cross-country skiing, snowmobiling, wildlife viewing, and personal solitude.

As some of our nation's most pristine areas, the parks also offer opportunities for scientists and resource managers from state, federal, and tribal agencies to better understand natural processes and to compare protected lands with more disturbed landscapes.

Climate

The region has a primarily mid-continental climate with seasonal temperatures that vary widely between summer highs and winter lows. The large bodies of water associated with these parks moderate temperatures, produce greater precipitation, and induce a slight seasonal shift to later summers on islands and immediate lakeshore areas in the Great Lakes parks (collectively known as 'lake effects'). Mean annual precipitation ranges from 64.5 to 90.7 cm (25.4 to 35.7 in), and temperatures can vary from minus 40 ˚C (-40 ˚F) in winter to over 32 ˚C (90 ˚F) in summer (Table 1.5; Appendix A, Supplemental Document 3). Annual snowfall ranges from 71.1 to 342.6 cm (28 to 135 in). Lake effect snowfall near the Great Lakes causes this wide variation in snowfall within and among parks in the Network. Two entries are included for SACN in Table 1.5 because significant climatic differences exist between the northern (Namekagon River) and southern (Lower St. Croix) reaches of the park due to latitude and topography.

Global climate change could have long-term ecological consequences for the region. Climate models suggest that temperatures around the Great Lakes will warm by 3 to 7 ˚C (5 to 12 ˚F) in winter, and by 3 to 11 ˚C (5 to 20 ˚F) in summer by the end of the 21st century (Kling et al. 2003). Kling et al. (2003) offer evidence that in the Great Lakes region, winters are already becoming shorter, average annual temperatures are getting

Table 1.5. Climate of the Great Lakes Inventory and Monitoring Network parks. Data from the National Climatic Data Center - National Oceanic and Atmospheric Administration (NOAA), Cooperative Summary of the Day (TD3200) data set; Jack Oelfke (NPS NOCA, personal communication) for ISRO. See Appendix A, Supplemental Document 3 for information on how numbers were derived.

Park	Mean annual temperature Average (Range)[1]	Annual precipitation Mean (Range)	Annual snowfall Mean (Range)	Growing season Mean (Range)
	°C (°F)	cm (in)	cm (in)	Number of days
APIS	5.3 (3.4 - 6.9) 41.5 (38.1 - 44.4)	78.5 (47.2 - 116.8) 30.9 (18.6 - 46.0)	234.4 (101.6 - 430.3) 92.3 (40.0 - 169.4)	140 (100 - 180)
GRPO	3.6 (2.7 - 5.7) 38.5 (36.9 - 42.3)	76.7 (55.4 - 99.6) 30.2 (21.8 - 39.2)	165.1 (76.2 - 264.2) 65.0 (30.0 - 104.0)	126 (102 - 146)
INDU	10.1 (8.6 - 11.7) 50.2 (47.5 - 53.1)	90.7 (63.5 - 133.1) 35.7 (25.0 - 52.4)	111.8 (43.2 - 167.6) 44.0 (17.0 - 66.0)	170 (133 - 201)
ISRO[2]	1 (range unavailable) 34 (range unavailable)	66 (range unavailable) 26 (range unavailable)	71 (range unavailable) 28 (range unavailable)	not available
MISS	7.3 (4.8 - 10.5) 45.1 (40.6 - 50.9)	69.9 (29.2 - 102.1) 27.5 (11.5 - 40.2)	134.9 (53.6 - 257.8) 53.1 (21.1 - 101.5)	163 (124 - 207)
PIRO	5.4 (3.0 - 7.1) 41.7 (37.4 - 44.8)	88.1 (65.5 - 121.4) 34.7 (25.8 - 47.8)	342.6 (108.5 - 510.0) 134.9 (42.7 - 201.2)	118 (74 - 176)
SACN - N	5.7 (3.1 - 8.8) 42.3 (37.6 - 47.8)	70.9 (26.7 - 115.1) 27.9 (10.5 - 45.3)	125.2 (45.7 - 247.9) 49.3 (18.0 - 97.6)	119 (72 - 166)
SACN - S	7.8 (5.9 - 10.4) 46.0 (42.6 - 50.7)	77.5 (49.0 - 114.0) 30.5 (19.3 - 44.9)	104.6 (34.5 - 191.5) 41.2 (13.6 - 75.4)	157 (122 - 195)
SLBE	7.6 (6.1 - 9.6) 45.7 (43.0 - 49.3)	87.9 (61.7 - 132.1) 34.6 (24.3 - 52.0)	322.6 (147.3-505.5) 127.0 (58.0-199.0)	148 (93 - 190)
VOYA	6.5 (0.7 - 6.6) 43.7 (33.3 - 43.9)	64.5 (43.4 - 89.4) 25.4 (17.1 - 35.2)	151.1 (63.8 - 330.2) 59.5 (25.1 - 130.0)	122 (59 - 158)

1 =Range, in this case, refers to the range of means in annual temperature.
2 =Data from Isle Royale are estimates; no range available.

warmer, duration of lake ice cover is decreasing, and heavy rain events are becoming more common. If predictions of further changes hold true, groundwater, surface water, wetlands, and other habitats could change dramatically and cause shifts in the distributions of many plants and animals.

Native Vegetation

The Network parks span two ecological provinces described by McNab and Avers (1994) - the Laurentian mixed forest and eastern broadleaf forest. Blouch (1984) also describes the area as a transitional vegetation zone between the boreal forest to the north and broadleaf forests to the south (Figure 1.1).

Quaking and big-tooth aspens (*Populus tremuloides and P. grandidentata*) and paper birch (*Betula papyrifera*) and are often the first tree species to become established following a disturbance. The forest types of less disturbed areas tend to reflect the region's soil and moisture regimes, with gradients existing both north-to-south and east-to-west. Common tree species of northern mesic forests include sugar and red maples (*Acer saccharum, A. rubrum*), red oak (*Quercus rubra*), yellow birch (*Betula alleghaniensis*), white ash (*Fraxinus americana*), basswood (*Tilia americana*), and white pine (*Pinus strobus*). To the east of the Minnesota-Wisconsin border, eastern hemlock (*Tsuga canadensis*) also occurs, and in the Michigan parks, American beech (*Fagus grandifolia*) is a common constituent. Southern mesic forests often contain many of the species found in northern forests with the following additional species: white and bur oaks (*Q. alba and Q. macrocarpa*), hickories (*Carya* spp.), and hackberry (*Celtis occidentalis*). Northern dry forests are typically dominated by jack pine (*Pinus banksiana*), red pine (*Pinus resinosa*), white pine, red oak, aspens, and paper birch. Southern dry forests usually do not contain pines, and instead are dominated by oak species with black cherry (*Prunus serotina*) co-occurring. Black and white spruce (*Picea mariana* and *P. glauca*), tamarack (*Larix laricina*), northern white cedar (*Thuja occidentalis*), black ash (*Fraxinus nigra*), and balsam fir (*Abies balsamea*) prevail in moist, northern forests. Southern wet forests are usually dominated by silver maple (*Acer saccharinum*), boxelder (*Acer negundo*), black willow (*Salix nigra*), green ash (*F. pennsylvanica*), swamp white oak (*Q. bicolor*), American elm (*Ulmus americana*), and cottonwood (*Populus deltoides*).

While forests are the dominant community type throughout the Network, other communities occur in limited areas. Oak savannas, prairies, dunes, and beaches are not widespread, yet constitute important habitats, often with specific park management goals. Wetlands are abundant and include types such as sedge meadow, marsh, swamp, and bog. Several parks contain old fields, some of which are succeeding to forest while others are maintained as part of the cultural history.

Fauna

Although disturbed by past human activities, the Network park ecosystems still contain most species of pre-European settlement wildlife. Extirpation of native fauna and invasion of exotics tend to be greatest at the southern end of the region. The southern areas are highly fragmented, dominated by human development, and include large cities such as Gary, Indiana; Chicago, Illinois; and Minneapolis-St. Paul, Minnesota. The aquatic environment supports a variety of fishes, amphibians, reptiles, semi-aquatic mammals, and waterfowl. White-tailed deer, which have greatly increased in number and range, are the dominant ungulates and have largely displaced moose and woodland caribou. Black bear (*Ursus americanus*), coyote (*Canis latrans*), and red fox (*Vulpes fulva*) are common terrestrial carnivores in the northern parks. Gray wolves (*Canis lupus*), which were extirpated from the contiguous 48 states by the early 1970s except for

ISRO and a small population in northeastern Minnesota, have steadily increased (Mech 2000). In addition to ISRO, wolves now occur regularly in VOYA, GRPO, and SACN and occasionally in APIS and PIRO. Beaver, which were once decimated by the fur trade, are again a major force in shaping the landscape at ISRO, VOYA, and SACN, and to a lesser degree at the remaining parks. Bald eagles (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), and other avian species high on the aquatic food chain are recovering from declines in the middle of the twentieth century caused by DDT and other pollutants (Gerrard and Bortolotti 1988). Migratory songbirds and waterfowl use the Mississippi and St. Croix rivers as major flyways between wintering grounds and summer breeding territories (Bellrose 1980). Similarly, migratory birds use islands at APIS and ISRO as stopovers to rest or stage while journeying across Lake Superior.

Threatened and Endangered Species

Federally endangered species are confirmed present in six of the Great Lakes Network parks (Table 1.6). Indiana Dunes and SACN both harbor three federally endangered species: piping plover (*Charadrius melodus*), Kirtland's warbler (*Dendroica kirtlandii*), and Karner blue butterfly (*Lycaeides melissa samuelis*) at INDU; Kirtland's warbler, Short's rockcress (*Arabis shortii*), and winged mapleleaf mussel (*Quadrula fragosa*) at SACN. The federally threatened bald eagle is present in all nine Network parks while the gray wolf is confirmed present in six. Other federally threatened species in Network parks include Pitcher's thistle (*Cirsium pitcheri*), at INDU, PIRO, and SLBE and Canada lynx (*Lynx canadensis*), at GRPO and VOYA.

Surface Water

Lakes - Six parks border Lake Superior or Lake Michigan (Table 1.4). These Great Lakes exert a dramatic effect on weather, species distributions, and animal migration patterns. Tens of thousands of smaller lakes ranging from < 10 to > 10,000 ha dot the region with density generally increasing from south to north. Voyageurs National Park, for example, has a complex of 30 lakes and hundreds of ponds. Lakes in the region vary greatly in productivity, but are generally ringed with aquatic plants (macrophytes) and provide habitat for fishes, amphibians, reptiles, semi-aquatic mammals, and a variety of waterfowl and other birds (LaBounty 1986).

Rivers - The Upper Mississippi River and its tributaries, including the St. Croix and Namekagon Rivers, span a latitudinal distance of over 1,280 km (800 mi) (Theiling 1996). Numerous smaller rivers and creek systems drain the region's surface waters down the Mississippi River to the Gulf of Mexico (SACN and MISS), northeast through the Great Lakes (GRPO, APIS, ISRO, PIRO, SLBE, and INDU), or north to Hudson Bay (VOYA).

Ponds and other wetlands - Hundreds of thousands of ponds and wetlands are interspersed through the region; like lakes, these become more frequent in the more northerly regions. These ponds and wetlands are sometimes associated with beaver activity, and in such cases, form some of the most productive wildlife habitats in the region (Omart and Anderson 1986, Weller 1986).

Table 1.6. Species with federal status in Great Lakes Inventory and Monitoring Network parks. Colors indicate park status (■ present, ■ probably present, ■ historic). Numbers indicate federal status (1 = endangered, 2 = proposed reclassification from endangered to threatened, 3 = threatened, 4 = proposed delisting, 5 = candidate, 6 = experimental population).

Species	Common name	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Vascular plants										
Arabis shortii	Short's rockcress					1		1		
Cirsium pitcheri	Pitcher's thistle			3			3		3	
Lespedeza leptostachya	prairie bush-clover					3		3		
Mimulus glabratus var. *michigansis*	Michigan monkeyflower								1	
Platanthera leucophaea	prairie white fringed orchid					3				
Birds										
Charadrius melodus	piping plover	1		1			1		1	
Dendroica kirtlandii	Kirtland's warbler			1				1		
Grus americana	whooping crane			1						
Haliaeetus leucocephalus	bald eagle	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4
Pelecanus occidentalis	brown pelican			1						
Sterna antillarum	least tern			1						
Mammals										
Canis lupus	gray wolf	2	3	2	2	3	2	2	2	3
Lynx canadensis	Canada lynx	3	3		3		3	3		3
Myotis sodalis	Indiana bat			1						
Herpetofauna										
Sistrurus catenatus catenatus	eastern massasauga			5					5	
Invertebrates										
Lampsilis higginsii	Higgins eye					1				
Lycaeides melissa samuelis	Karner blue butterfly			1						
Quadrula fragosa	winged mapleleaf							1,6		

Summary of Past and Ongoing Terrestrial Studies

The majestic nature of many Network parks has long been a draw for researchers of terrestrial ecosystems, with many early studies of terrestrial resources conducted prior to the National Park designations. These early studies (1900 - 1950) tended to focus on the compilation of species lists, especially of a region's flora. For example, plant species lists were compiled for ISRO in 1914 and for SLBE in 1918. More recent terrestrial research has focused on the relationships of species with their larger environment. Common concerns across parks include the effects of deer browse on vegetation, anthropogenic influences on bears, and the role of fire on park ecosystems. Most recently (1990 - present), many studies have addressed habitat issues for taxa of concern. Notable examples include research at INDU on a native lupine (*Lupinus perennis*), the only food source of the federally endangered Karner blue butterfly. Similarly at SLBE, fields that are maintained for cultural reasons were examined for their importance to declining grassland bird communities.

While most terrestrial studies address a single point in time, several have examined longer time frames. Surveys of deer at INDU and MISS, and wolves at ISRO and moose at GRPO, are, or have been, conducted annually. Breeding bird surveys are also conducted annually at most of the Network parks, and a Christmas bird count has been conducted at INDU since 1953. Long-term studies have not been limited to species surveys. In what is considered a hallmark of long-term research, the population dynamics of the wolf-moose predator-prey system at ISRO have been examined since the early 1960s.

A summary of studies of terrestrial resources at the nine parks in GLKN is available in Appendix A, Supplemental Document 4. The authors provide a synopsis of research from each park, with a focus on floral, mammalian, and avian studies.

Summary of Past and Ongoing Aquatic Studies

A variety of aquatic resource investigations have taken place at Network parks since the parks were established (Lafrancois and Glase 2005). At many parks, these studies have been primarily descriptive, providing general characterizations of park waters and assessments of basic physical, chemical, and/or biological conditions. All Network parks have baseline water quality information for at least some of their waters. This information varies in quality, is sometimes dated, and may include early qualitative surveys as well as more recent inventories and quantitative studies. Benthic invertebrate community assessments have been undertaken in several Network parks since the 1980s. Phytoplankton, zooplankton, and aquatic macrophytes are less frequently studied, and functional aspects of aquatic ecosystems (productivity, nutrient cycling, etc.) are not usually considered.

Aquatic wildlife and amphibians have often been the subject of inventory and monitoring efforts, but rarely the topic of specific research programs. Fisheries investigations have varied among parks, but have consisted largely of surveys and assessments. Much of the fisheries information available for parks comes from state investigations. The U.S. Geological Survey (USGS) has streamflow gages in or near all parks except PIRO, which in some cases are used for water quality monitoring or research projects.

Several parks have developed or are developing water resource management plans (SACN, SLBE, VOYA, and ISRO). Water resources scoping projects, assisted by the NPS Water Resources Division, are planned for MISS and PIRO. These documents play a key role in prioritizing research needs and maintaining continuity in park aquatic research activities.

Detailed analyses of trends in water quality using past data are not possible for most GLKN parks because data collection methods were inconsistent, laboratory analysis methods were often undocumented, and other metadata were often lacking. Despite these inconsistencies and the project-specific nature of past water quality sampling, we have been able to determine hints of trends at several parks, as detailed below.

- The draft water resources management plan for ISRO (Crane et al. 2005) summarized trends in water quality as follows. Inland lakes, while sampled incompletely, show no discernable trends from the 1970s to 1990s in chemical and biological parameters, with the exception of a decline in sulfate concentration. Sediment cores from Siskiwit Lake (ISRO) show declines in persistent organic pollutants and poly-aromatic hydrocarbons; lake trout tissue has shown concomitant declines in these and other pollutants.
- Lafrancois et al. (in press) analyzed data from Lake St. Croix (SACN) from 1976 to 2004, and found decreasing trends in total nitrogen, ammonia plus ammonium nitrogen, total phosphorus, ortho-phosphate, total suspended solids, and turbidity; nitrate plus nitrite nitrogen showed an increasing trend; total chlorophyll-*a* and flow showed no significant trends. Similar analyses of data from 1993 to 2003 showed fewer significant trends, however, total chlorophyll-*a* increased, and flow decreased. Triplett et al. (2003) analyzed diatom communities in sediment cores from Lake St. Croix, and concluded that current sedimentation rates are four times that of pre-European settlement times, approximately 170 years ago, and phosphorus loads are approximately three times greater. In response to the increased phosphorus loading, algal abundance and community structure have changed greatly since pre-settlement times.
- Kallemeyn et al. (2003) describe declines in sulfate deposition in the area near VOYA between 1980 and 2000, and show similar declines in the four large lakes. Eleven interior lakes showed an increase in acid neutralizing capacity over the same approximate time period, and a similar, but weak increasing trend in pH.

Axler et al. (2006) conducted exploratory trend analyses of inland lakes at SLBE, PIRO, and INDU, and found dozens of potential trends in several parameters, but predominantly dissolved oxygen, pH, and specific conductance. At SLBE, for example, four lakes showed an increasing trend in dissolved oxygen (linear regression results) in the 1-3 m depth stratum, two lakes showed a similar increase in the 6-7 m stratum, and two lakes showed a decreasing trend in the 1-3 m stratum. At PIRO, two lakes showed decreasing trends in pH - Grand Sable Lake in both the 6-7 m and 13-14 m depth strata, and Legion Lake in both the 1-3 m and 9-10 m strata. Some of these trends may indeed be real, but because Axler et al. (2006) conducted multiple tests without Bonferroni corrections and used a high p-value (10%), their results must be viewed as exploratory. A detailed aquatic synthesis of all nine GLKN parks has been prepared as a technical report (Lafrancois and Glase 2005). For each park, the authors describe the basic aquatic resources; summarize past aquatic-related research, inventory, and monitoring efforts; identify the strengths and gaps in aquatic resource programs; and make recommendations for monitoring and research. This aquatic synthesis also includes information relevant to the Network as a whole, such as a summary of aquatic projects undertaken in parks by aquatic theme (e.g., water quality, contaminants, mussels, fish). The authors point out apparent information needs for inventory, monitoring, and research across the Network, and provide recommendations.

Summary of Water Resource Threats and Legal Status

Water is a major natural resource of the nine GLKN parks, and NPS mandates clearly state the need to protect water resources. The NPS Strategic Plan 2001-2005 provides goals and guidelines for water quality. In the Omnibus Management Act of 1998, Congress required that park managers provide a "*program of inventory and monitoring of the National Park System resources*."

The majority of Network parks have good water quality (Table 1.7). However, the amount of historic water quality data available for each park varies widely, which makes comparisons difficult (see Ledder 2003 for a complete discussion). Atmospheric deposition and surrounding land use practices are two of the most common threats to water quality in the parks. Three parks (INDU, MISS, and SACN) are located in urban settings and have been negatively impacted by residential and industrial activities. Seven parks have one or more waterbodies listed in the corresponding state 303(d) list of impaired waterbodies due to air deposition of toxics and land use practices. Conversely, eight parks contain waterbodies considered to be Outstanding Resource Waters (ORW) by the corresponding state, including seven of the same parks with 303(d)-designated waters (Tables 1.7 and 1.8). Methylation and bioaccumulation of mercury are issues at most, if not all, parks (Crane et al. 2005, Kallemeyn et al. 2003, Ledder 2003).

Regulations for maintaining water quality in Network parks include Water Quality Standards in Minnesota, Wisconsin, Michigan, and Indiana. All but three parks are located in the Great Lakes Basin and fall under the Great Lakes Water Quality Agreement between the United States and Canada.

Summary of Air Quality Information

The NPS Air Resources Division (ARD) conducted a synoptic overview of air quality monitoring considerations for Network parks (Maniero and Pohlman 2003). The following is a summary of conclusions from that report.

Ambient air quality in Network parks appears to be generally well monitored (Figure 1.2). All nine parks have wet deposition (i.e., National Atmospheric Deposition Program/National Trends Network (NADP/NTN)) sites within 56 km (35 mi) of their boundaries. With the exception of VOYA, which has a dry deposition (i.e., Clean Air Status and Trends Network (CASTNet)) site, all other parks are between 72 km (45 mi) and 264 km (165 mi) from the nearest CASTNet site. The distance between parks and CASTNet monitoring is not unusual, given the small number of CASTNet monitoring stations across the country. The relative abundance of wet deposition monitors is probably appropriate because the bulk of the deposition in this area is in the form of wet deposition (Maniero and Pohlman 2003).

Most Network parks have ozone monitors within 40 km (25 mi) of their boundaries. The exception is APIS with the nearest ozone monitor 112 km (70 mi) away.

Table 1.7. Summary of threats to water resources at the nine National Park Service units in the Great Lakes Inventory and Monitoring Network (Ledder 2003). Under legal status, 303(d) = impaired waterbody; and ORW = Outstanding Resource Waters.

Park	State	Data	Current status and threats to water resources	Documented problem parameters*	Waterbody legal status#
Apostle Islands National Lakeshore	WI	1968-1996	Appears to be good quality. Atmospheric deposition and water traffic/recreational use. Highly erodible soils and often severe spring runoff.	None documented	None designated
Grand Portage National Monument	MN	1968-1995	Appears to be good quality. Relatively little water quality data. Atmospheric deposition, light recreational use, and logging in surrounding areas.	Pigeon River outside boundary 303d-listed for mercury	Pigeon River outside boundary is 303(d) listed
Indiana Dunes National Lakeshore	IN	1935-1992	Impacted by industrial/municipal effluents, surface runoff, sulfur and nitrous oxides, altered hydrologic processes, exotic species, and drain and fill of wetlands.	PCBs, PAHs, metals, pesticides, fuels and oils, indicator bacteria, biota	Outstanding Resource Waters (ORW), 303(d) listed waters
Isle Royale National Park	MI	1962-1987	Appears to be very good quality. Atmospheric deposition, visitor activities, and waste.	Mercury, PCBs	303(d) listed waters Whole park ORW
Mississippi National River and Recreation Area	MN	1926-1994	Heavily impacted by industrial/municipal waste water discharges, stormwater runoff, commercial and residential development, contaminated sediments, and erosion.	Dissolved oxygen, metals, indicator bacteria	303(d) listed waters Headwaters ORW
Pictured Rocks National Lakeshore	MI	1968-1984	Appears to be good quality. Atmospheric deposition, surrounding land use practices and development, invasive species, and viewshed impacts.	None documented	303(d) listed lakes Whole park ORW
Saint Croix National Scenic Riverway	WI	1926-1995	Impacted by development, industrial/municipal wastewater discharges, surface runoff, agriculture, cranberry industry, and recreational use.	Dissolved oxygen, metals, indicator bacteria, mercury, and PCBs	ORW rivers 303(d) listed lakes and flowages on the rivers
Sleeping Bear National Lakeshore	MI	1962-1996	Appears to be good quality. Atmospheric deposition, non-native species, septic leakage, wastewater, runoff, and recreational use.	None documented	303(d) listed lakes Whole park ORW
Voyageurs National Park	MN	1967-1991	Appears to be good quality. Atmospheric deposition, human use and adjacent land uses. Naturally occurring low yield aquifers may limit groundwater use.	Mercury, PCBs, fuels, waste water	Whole park ORW

* Denotes historic data gathered in "Baseline Water Quality Inventory and Analysis Reports"
\# Denotes Water Quality Standards and state lists.

Table 1.8. Waterbodies with legal designation in the Great Lakes Inventory and Monitoring Network.

Park	Waterbody	Legal status	Reason for 303(d)
APIS	Lake Superior Lake Superior and tributaries for ¼ mile	303(d) 303(d)	FCA for PCBs, Hg, chlordane, dioxin FCA for Hg
GRPO	Pigeon River (outside of park boundaries) Lake Superior	303(d) ORVW	Hg FCA for PCBs, Hg, chlordane, dioxin
INDU	Grand Calumet River Little Calumet River Lake Michigan all waterbodies	303(d) 303(d) OSRW/303(d) OSRW	FCA for PCBs & Hg; CN, oil, pesticides, impaired biota, *E. coli*, Cd, Zn, PAH *E. coli*, CN, pesticides, DO FCA for PCBs, Hg, chlordane, dioxin
ISRO	Siskiwit Lake Lake Superior all waterbodies	303(d) OIRW/303(d) OSRW/303(d)	FCA for PCBs, Hg FCA for PCBs, Hg, chlordane, dioxin FCA-Hg
MISS	Mississippi River Mississippi River (portions)	303(d) ORW	Aquatic life, turbidity, PCB, bacteria
PIRO	Grand Sable Lake Lake Superior all waterbodies	303(d) OIRW/303(d) OSRW/303(d)	Hg FCA for PCBs, Hg, chlordane, dioxin FCA for Hg
SACN	St. Croix Flowage Minong Flowage Yellow Lake Mud Hen Lake Sunrise River Goose Creek St. Croix River Namekagon River Kettle River	303(d) 303(d) 303(d) 303(d) 303(d) 303(d) ORW/303(d) ORW ORW	Hg Hg Hg Hg Aquatic life, impaired biota, indicator bacteria Excessive nutrients Bioaccumulative toxins
SLBE	Lake Michigan Big Glen Lake Little Glen Lake all waterbodies	303(d) 303(d) 303(d) OSRW/303(d)	FCA for PCBs, Hg, chlordane, dioxin FCA-PCB, chlordane, Hg FCA-PCB, chlordane, Hg FCA for Hg
VOYA	all waterbodies	ORVW/303(d)	FCA for Hg

303(d) = impaired waterbody
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
OIRW - outstanding international resource water
ORVW = outstanding resource value waters (MN designation)
ORW = outstanding resource waters (WI Designation)
OSRW = outstanding state resource waters (IN & MI designations)
FCA= fish consumption advisory for atmospheric deposition
Hg = mercury

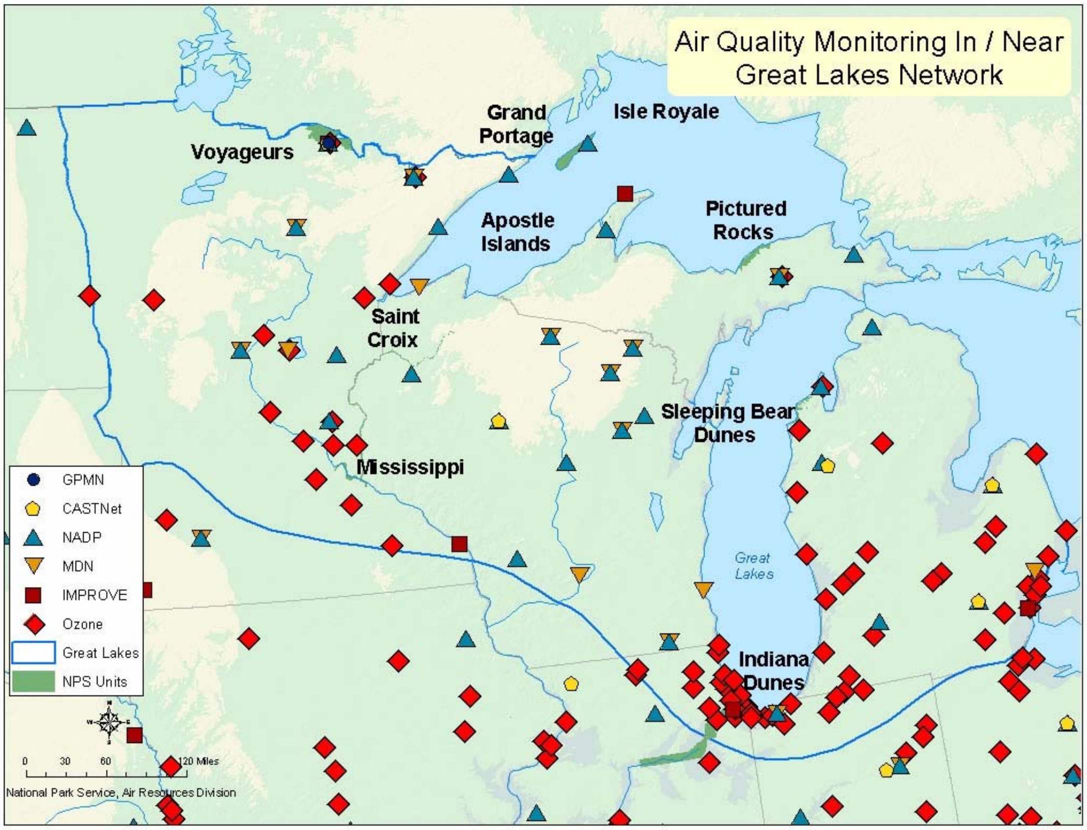


Figure 1.2. Location of air quality monitoring stations in the area surrounding the Great Lakes Inventory and Monitoring Network. GPMN = Gaseous Pollutant Monitoring Network, CASTNet = Clean Air Status and Trends Network, NADP = National Atmospheric Deposition Program, MON = Miscellaneous Organic National Emission Standards for Hazardous Air Pollutants, IMPROVE = Interagency Monitoring of Protected Visual Environments.

Parks with Class I airsheds have either on-site (VOYA) or nearby (ISRO) Interagency Monitoring of Protected Visual Environments (IMPROVE) monitors. (Class I, II, and III areas are Congressional classifications designed to prevent deterioration of air quality. Class I airsheds receive the greatest protection and Class III the least.) For other parks, proximity to an IMPROVE monitor largely depends on how close the park is to a Class I park or another Class I area (such as the Boundary Waters Canoe Area Wilderness or the Seney National Wildlife Refuge (NWR)). The distance of parks with Class II airsheds from IMPROVE monitors range from 40 to 224 km (25 to140 mi). Monitoring visibility at scenic vistas with digital cameras is possible; while not adequate for regulatory purposes, it is useful for documenting visibility conditions and trends and providing a means of sharing that information with the public. Cameras are currently located at Seney NWR, Michigan, approximately 50 km (31 mi) from PIRO, and Grand Portage Indian Reservation, Minnesota, adjacent to GRPO (www.mwhazecam.net/).

A fair amount of ambient air toxics monitoring has been and is being conducted in the Great Lakes area. These efforts do not seem to be well coordinated on a regional basis, and the data from the various monitoring programs are not readily available. Air toxics may be an issue for many Network parks. A great deal of monitoring and research on these toxic effects has been conducted at INDU, ISRO, MISS, SACN, and VOYA. For good reason, monitoring at ISRO and VOYA has focused on mercury and its effects. Additional previous work at ISRO focused on atrazine and PCBs. Very little, or no, monitoring on the effects of air toxics has been conducted at APIS, GRPO, PIRO, or SLBE. The ARD also looked at park water quality data relative to atmospheric deposition for all nine Network parks. The data indicated that surface waters at APIS (i.e., island lagoons) are sensitive to acidification from atmospheric deposition. Nitrogen deposition associated eutrophication may be a concern for INDU and MISS.

Ozone sensitive vascular plant species have been identified for all of the parks in the Network. Ozone concentrations may be high enough in INDU, PIRO, and SLBE that foliar injury surveys are warranted. An ARD-funded risk assessment completed for Network parks in June 2003 provided further guidance on the likelihood of ozone-induced vegetation damage.

Summary of Current Monitoring in Parks

Network staff are cataloging and evaluating monitoring projects that are ongoing in the nine parks. This work is a component of the overall data mining effort being conducted by the Network's data specialists. The extent of monitoring efforts varies among parks, and is a consequence of park size, longevity, and natural resource program funding.

Network-wide, at least 217 projects with over 1,300 cumulative years of data collected have been conducted by NPS staff, other agencies, and academic partners (Table 1.9). The number of projects is subjective, however, because each park counts them differently. For example, one park may count five field sessions to monitor five species of invasive plants as five projects, while another park may count the entire effort as one monitoring project for invasive plants. Regardless, Figure 1.3 and Table 1.9 illustrate the relative effort among natural resource subjects. The greatest monitoring efforts in parks have been on birds, plants, and water quality, in that order. Much of the bird monitoring follows standardized protocols such as those of the breeding bird survey (BBS), or those recommended by Howe et al. (1997), but significant efforts are directed at specific species or assemblages such as the bald eagle, piping plover, and colonial water birds. Most plant monitoring revolves around non-native, sensitive, and rare species. Some selected plant communities (e.g., sand dune communities) or species (e.g., Canada yew (*Taxus canadensis*) are also being monitored and several parks are cooperating with the U.S. Forest Service to gather Forest Health Monitoring (FHM) plot data. Most Network parks or their partners are monitoring basic water chemistry and some indication of flow or lake level. Other significant efforts include air quality, fire effects (fuels and vegetation changes), fish communities, amphibian call surveys, white-tailed deer, and human impacts. The most notable long-term study is the wolf/moose predator prey study on Isle Royale. This study is currently conducted by Rolf Peterson from Michigan Technological University with support from the NPS. The study has been conducted, without interruption, for over 40 years, and has resulted in numerous scientific and public interest publications. Refer to Appendix A, Supplemental Document 5 for a complete listing and abstracts of unpublished reports on ecological monitoring in

Network parks, and Supplemental Document 6 for important published literature on ecological monitoring.

Current monitoring projects within the Network parks provide a good basis for a more focused monitoring program. Considerable information can be gleaned from these projects. For example, data variability, logistical constraints, and relative estimates of cost will all be essential for the future development of the Network program. Unfortunately, few of these efforts are well analyzed and reported. In 2003, the Network contracted with the University of Minnesota, Natural Resources Research Institute (NRRI) to analyze and summarize water quality monitoring data collected in the nine parks. In their draft report, they made recommendations for improvement in monitoring methods at several Network parks. The Network also hired a private contractor in 2003 to critique the parks' monitoring of herpetofauna (Casper 2004). The contractor's final report included recommendations for consistency across the parks as well as for methods specific to individual parks. In FY04, the Network selected contractors to assess park data for the additional monitoring themes of bioaccumulation of toxins, terrestrial vegetation, breeding landbirds, and deer browse.

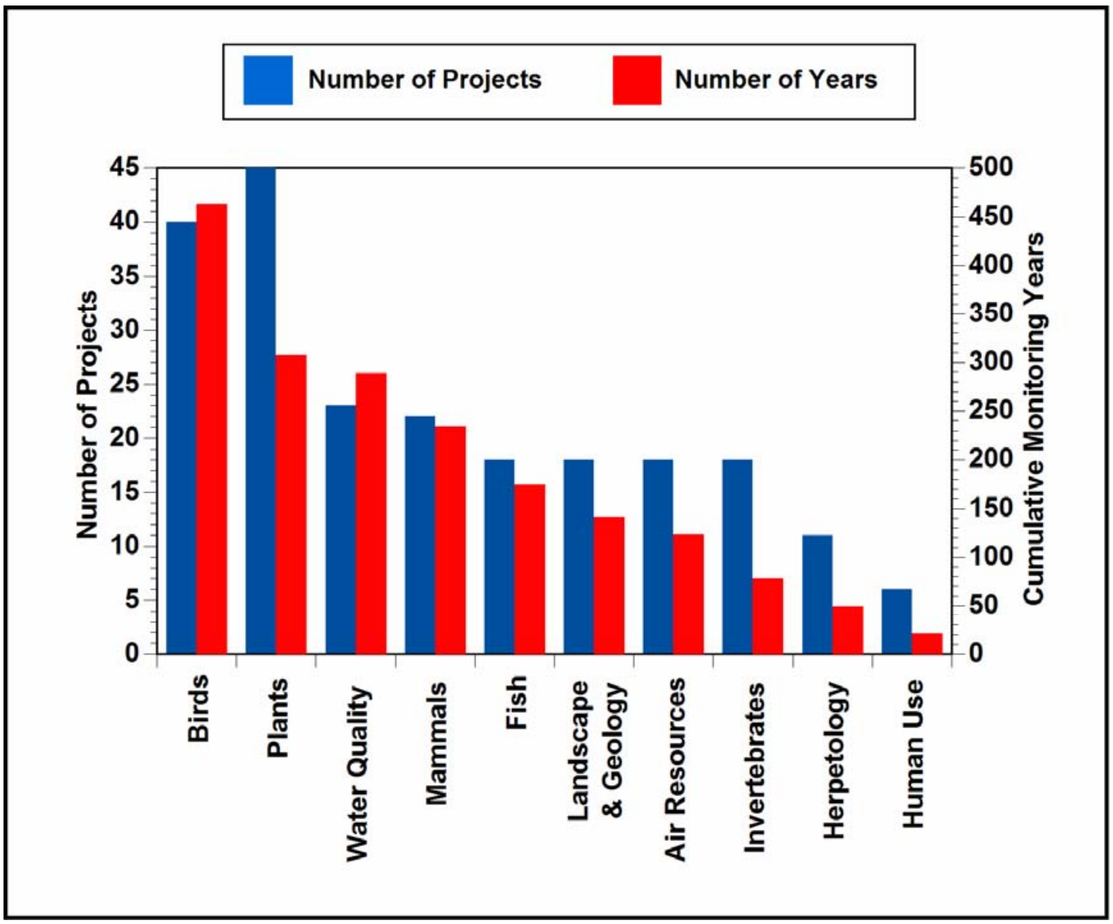


Figure 1.3. Summary of the number of projects and cumulative years of data collected for all known monitoring activities in National Park Service units of the Great Lakes Inventory and Monitoring Network. This summary includes efforts by NPS staff and numerous other agency and university partners.

Table 1.9. Past and current monitoring efforts by the National Park Service and its partners in the Great Lakes Inventory and Monitoring Network. Numbers reflect total known projects in each category as of December 2004.

Ecosystem component	Great Lakes Network Parks									
	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA	Total
Air resources										
Meteorology			1	1				1	1	3
Air quality	1		1	1				1	1	5
Ozone			1	1					1	3
Mercury and other pollutants			1					1		2
Wet deposition			1	1					1	2
Fire weather			1					1		2
Water quality										
Physical: temp., cond., pH, clarity	1	1	1		3	1	1	1	2	11
Nearshore bacteriology			1					1		2
Riparian – Riverwatch			1		1					2
River flow/river flow/lake levels					2		2	1	1	6
Sedimentation					1			1		2
Geology and landscape processes										
Bluff erosion	1							1		2
Sandscape/beach erosion	1		1			1	1			4
Fire/habitat processes			3	2					1	6
Hydrology								2		2
Land use monitoring					3			1		4
Plants										
Selected plant communities	2	1	2		1	1		1	1	9
Exotic plants	2		2	1	1	2	2	4	1	15
Sensitive, rare and threatened plants	2		3	1		1	1	3		11
Plant health and disease			1	1		2			2	6
Invertebrates										
Aquatic invertebrate communities					2				1	3
Sensitive, rare and threatened species			1				1	1		3
Gypsy moth	1		1	1		1		1	1	6
Zebra mussel						1	1	1	1	4
Other exotic invertebrates				1					1	2
Fisheries										
Salmonids – coaster brook trout, etc.		1		1		1				3
Nearshore fisheries		1	1						1	3
Sportfish harvest									4	4
Fish ecosystem					3		1		3	7
Exotic fish						1				1
Reptiles and amphibians										
Anuran call survey	1		1	1	1	1	1	1		7
Other herp community				1			2			3
Amphibian deformity				1						1
Birds										
Breeding bird survey	1	1	1	1	1	1	1		1	8
Migratory bird survey	1									1
Winter bird survey							1			1
Colonial waterbirds	1		1	1			1	1	2	7
Game birds	2	1								3
Bald eagle	1			1		1	1	1	2	7
Piping plover	1		1			1		1		4
Other avian T&E species							1	1		2
Special concern avian species			5	1				2	2	10
Mammals										
Ungulates	1	1	2		1			1	2	8
Beaver	1			1			1		2	5
Black bear	1					3			1	5
Timber wolf				1						1
Other mammal							2		1	3
Human uses										
Human impacts				1			3	1	1	6
Total	22	7	35	22	20	19	24	32	33	217

Significant Monitoring Programs in the Great Lakes Region

Several important monitoring efforts are being conducted by partners around the region. Most of these are captured in the 'current monitoring' discussion above. Three additional programs that are significant to the Network's goals are summarized below.

State of the Lakes Ecosystem Conference (SOLEC): http://www.epa.gov/glnpo/solec/

Canada and the United States are parties to the Great Lakes Water Quality Agreement (GLWQA). In 1994, the U.S. Environmental Protection Agency (EPA) and Environment Canada began hosting the biennial State of the Lakes Ecosystem Conferences (SOLEC) to report on the condition of the Great Lakes ecosystem and the major factors impacting it. After each conference, the EPA and Environment Canada prepare a report on progress towards achieving the purpose of the GLWQA: *to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Ecosystem*. The SOLEC partners include all major federal, state, and provincial agencies, and NGOs in both countries. The partners have selected 80 indicators that reflect conditions of the Great Lakes basin and its major components. Currently 33 indicators are being reported on, but more indicators are incorporated at each conference.

The Network considered the 80 SOLEC indicators during focus meetings for the selection of Vital Signs. Many of the SOLEC indicators are not appropriate to the GLKN because of scale and different goals; however, some were included on GLKN's list. The Network's coordinator serves on the SOLEC Steering Committee.

Great Lakes Ecological Indicators (GLEI) program: http://glei.nrri.umn.edu/default/

The EPA funded the University of Minnesota's Natural Resources Research Institute to conduct a four-year evaluation of ecological indicators for the Great Lakes Basin. The study involves a rigorous research design to test field methods, statistical models, measurability, and overall relevance of a suite of indicators for nearshore and terrestrial components of the Great Lakes Basin. The field portion of the study concluded in 2005 and data analyses will continue for one to several years. The principal investigator for the GLEI program serves on GLKN's Science Advisory Group (SAG) and other NRRI employees are involved in analysis of past data and in helping develop protocols for the Network.

Amphibian Research and Monitoring Initiative (ARMI): www.armi.usgs.gov

The USGS Amphibian Research and Monitoring Initiative (ARMI) formed in 2000 over concern for worldwide population declines and physical deformities in amphibians. Because of their close association with aquatic habitats and sensitivity to environmental stresses, amphibians are good indicators of ecosystem health. The purpose of ARMI is to measure, understand, and respond to the effects of environmental change on the nation's amphibians. The ARMI coordinator for the North Central region, who serves on GLKN's Science Advisory Group, is stationed at the Upper Midwest Environmental Science Center in La Crosse, Wisconsin. The Network and ARMI have a joint project to inventory amphibians and reptiles at SACN, MISS, and VOYA.

Forest Inventory and Analysis (FIA)t: www.fia.fs.fed.us

The forest inventory and analysis program (FIA) is managed by the USDA Forest Service in cooperation with state forestry programs and private industry. FIA has been in operation under various names (e.g. Forest Survey) for over 70 years. The program reports on status and trends in forest area; composition, size, and health of trees; in total tree growth, mortality, and harvest; in wood production and utilization rates; and in forest land ownership. The Forest Service has recently enhanced the FIA program by changing from a periodic survey to an annual survey (i.e. monitoring) and by expanding the scope of data collection to include soil, under story vegetation, tree crown conditions, coarse woody debris, and lichen community composition. The Great Lakes Network is currently intending to monitor terrestrial vegetation using methods that conform to FIA so that network data can be put in to regional context with this extensive dataset.

USGS Long Term Resource Monitoring Program: http://www.umesc.usgs.gov/ltrmp.html

The Long Term Resource Monitoring Program is being implemented by the U.S. Geological Survey (USGS) in cooperation with the five Upper Mississippi River System states (Illinois, Iowa, Minnesota, Missouri, and Wisconsin), with guidance and overall responsibility provided by the U.S. Army Corps of Engineers. Congress has recognized the Upper Mississippi River System as both a nationally significant ecosystem and a nationally significant commercial navigation system. The long-term goals of the Program are to understand the system, determine resource trends and impacts, develop management alternatives, manage information, and develop useful products. The Great Lakes Network has engaged USGS scientists involved with this program to help develop ecosystem models and we have learned from many of their past efforts.

USGS - Water Resources Discipline: www.*water.usgs.gov/programs*

There are several USGS WRD programs active in the Great Lakes region and the upper Mississippi River Basin. These include: the Cooperative Water Program, a partnership between the USGS and state and local agencies; the National Streamflow Information Program (NSIP) for the delivery of streamflow information; the National Water Quality Assessment Program (NAWQA), which since 1991, has helped develop long-term data on streams, ground water, and aquatic ecosystems, and the Biomonitoring of Environmental Status and Trends (BEST) Program, which has conducted long-term research and assessments of the effects of contaminants on the upper Mississippi River.

Other programs:

In addition to the above large-scale monitoring programs, each of the four states and some local jurisdictions (e.g. Minneapolis-St. Paul Metropolitan Council) that surround the network parks monitor a variety of natural resources. States routinely monitor water quality, fish and wildlife populations and harvest levels, amphibians, the release and accumulation of toxic chemicals, forest resources, and a variety of rare and exotic species. It is beyond the scope of this document to summarize this extensive work; each protocol will delve in more detail in to relevant state monitoring efforts. The Great Lakes Network is making every attempt to be consistent with other state and federal programs if it meets our objectives and is scientifically defensible.

Chapter 2 – Conceptual Models

INTRODUCTION

A conceptual model is a visual or narrative summary (or both) that describes the important components of an ecosystem and the interactions among those components (NPS 2003). Although they are simplifications of complex systems (Starfield 1997), models help synthesize current scientific understanding so that scientists can make defensible decisions on what to monitor with a better understanding of how indicators are linked to the broader ecosystem (DeAngelis et al. 2003, Maddox et al. 1999).

Weaknesses of past monitoring programs often stem from a lack of underlying heuristic models upon which the monitoring questions, sampling designs, analyses and interpretations were predicated (Niemi and McDonald 2004, Noon 2003, Noon et al. 1999). Well-designed conceptual models help formalize current understanding of system processes and dynamics, identify linkages of processes across disciplinary boundaries, identify the bounds and scope of the system of interest, and contribute to communication among all stakeholders. This chapter summarizes the process we used to develop and incorporate conceptual models in the selection and interpretation of Vital Signs for the GLKN parks.

Ecosystems and Authorship

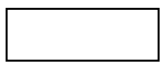
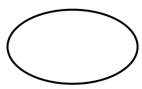
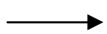
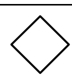
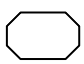
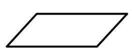
We selected six broad conceptual models: geological processes, inland lakes, Great Lakes, large rivers, northern forests, and wetlands. Network staff enlisted scientists with knowledge of these ecosystems or processes and a familiarity with the Network parks to write the conceptual models (Table 2.1).

Table 2.1. Great Lakes Inventory and Monitoring Network conceptual model authors and affiliations.

Model	Author(s)
Geological Processes	Walter Loope, USGS Great Lakes Biological Station
Inland Lakes	Paul Sager, UW-Green Bay
Great Lakes	Glenn Guntenspergen, USGS Patuxent Wildlife Research Center
Large Rivers	Ken Lubinski, USGS Upper Midwest Environmental Sciences Center
Northern Forests	Jerry Belant, NPS Pictured Rocks National Lakeshore Phyllis Adams, NPS Midwest Regional Office
Wetlands	Joan Elias, NPS Great Lakes Inventory and Monitoring Network Darin Carlisle, USGS Water Resources Division

The GLKN selected a stressor-based modeling approach to indicate links among important **stressors** and affected attributes. Model authors were asked to produce a narrative report with box-and-arrow schematics to represent key ecosystem components and linkages (Table 2.2). The combined strengths of the narrative and box-and-arrow diagrams convey important information and provide clear links to management issues.

Table 2.2 Components of the "Box-and-Arrow" conceptual models used by the Great Lakes Inventory and Monitoring Network to identify Vital Signs (adapted from NPS 2003).

Symbol	Model Component
	*Drivers* are major driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that influence natural systems across large areas.
	*Stressors* are physical, chemical, or biological perturbations to a system that are either foreign to that system or natural to the system but occurring at an excessive or deficient level. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include air pollution, water pollution, water withdrawal, pesticide use, timber and game harvest, and land-use change. They act together with drivers on ecosystem attributes.
 or 	*Ecological effects* are the physical, chemical, biological, or functional responses of ecosystem attributes to drivers and stressors.
	*Attributes** are any living or nonliving environmental feature or process that can be measured or estimated to provide insights into the state of the ecosystem.
	*Measures* are the specific variables used to quantify the condition or state of an attribute or indicator. These are specified in definitive sampling protocols. For example, stream acidity may be the indicator; pH units are the measure.

* Vital Signs are a subset of attributes that are determined to be the best indicators of ecological condition, or respond to natural or anthropogenic stresses in a predictable or hypothesized manner, or have high value to the park or the public (e.g., endangered species, charismatic species, exotic species).

RESULTS OF MODELING

The six conceptual models are presented in their entirety in Gucciardo et al. (2004); a brief overview of each model is provided below along with its associated diagram. These conceptual models may need to be refined and expanded as the Network matures, collects monitoring data, and focuses on specific indicators. Nonetheless, the models in their current form provided a common understanding of the ecosystems and were used as a tool to help select the most critical Vital Signs for monitoring. The diagrams helped illustrate major causes of change (drivers and stressors) and how they are linked ecologically to potential measures.

Earth Processes (Figure 2.1)

General description

This model describes the geological and physical processes that formed and continue to modify the land in and around the Great Lakes Network parks. The entire upper Midwest was influenced by glaciers as recently as 10,000 years ago. The resulting landforms, soils and dynamic processes (e.g., erosion) in turn influence other terrestrial and aquatic systems.

Drivers and stressors

Climate is a major driver which causes natural fluctuations of Great Lakes water levels. This variability has driven quasi-periodic (approximately 150 years) lake level change over at least the past 5000 years (Thompson and Baedke 1997, Baedke and Thompson 2000). High lake levels have influenced coastal dune building and local hydrology (Anderton and Loope 1995, Loope and Arbogast 2000). Thus, the shores of several Network parks are naturally quite dynamic. Lake-level fluctuations drive changes in patch size, shape, and distribution of habitats required by several rare plant species. Along sandy portions of the Upper Great Lakes shorelines, propensity to change can differ greatly with position relative to streams of littoral sand drift and the texture of bluff substrate. The same lake level and storm surge behavior can result in bluff retreat, recession, or progradation depending on location (Chrzastowski and Thompson 1992).

All nine Network parks were covered by Wisconsinan glaciers, which left behind glacial drift (outwash, till, and lacustrine deposits) of various thicknesses. Upland landforms are subject to natural and anthropogenic erosion and sedimentation processes. Unconsolidated sandy deposits commonly occurring along lower landscape positions are regularly destabilized by natural fluctuations of the Great Lakes water levels (Bishop 1990, Colman et al. 1994, Anderton and Loope 1995, Arbogast and Loope 1999, Fisher and Whitman 1999).

Changes to natural features and processes often stem from construction of roads, trails, buildings, and other facilities. Alteration of natural processes most commonly results from placement of structures such as revetments, groins, and other shore armoring. Compaction of soils and hardening of the surface (i.e., pavement) along the shoreline of lakes and streams causes increased rates of water runoff and adds to sediment loads, pollution, and erosion. Visitor trampling can also compromise vegetation and promote erosion, though normally at a smaller scale. Human-caused changes in climate could result in altering water levels and changing the hydrological cycle.

Indicators

Some important indicators within the Earth Processes model include rates of soil transport, rates of bluff retreat, rates of beach recession/progradation, stream bank stability, stream sinuosity and erosion, dune building and stabilization, populations of rare shoreline plants, stream sediment load, longshore sediment transport, stream flow regime, and Great Lakes water levels.

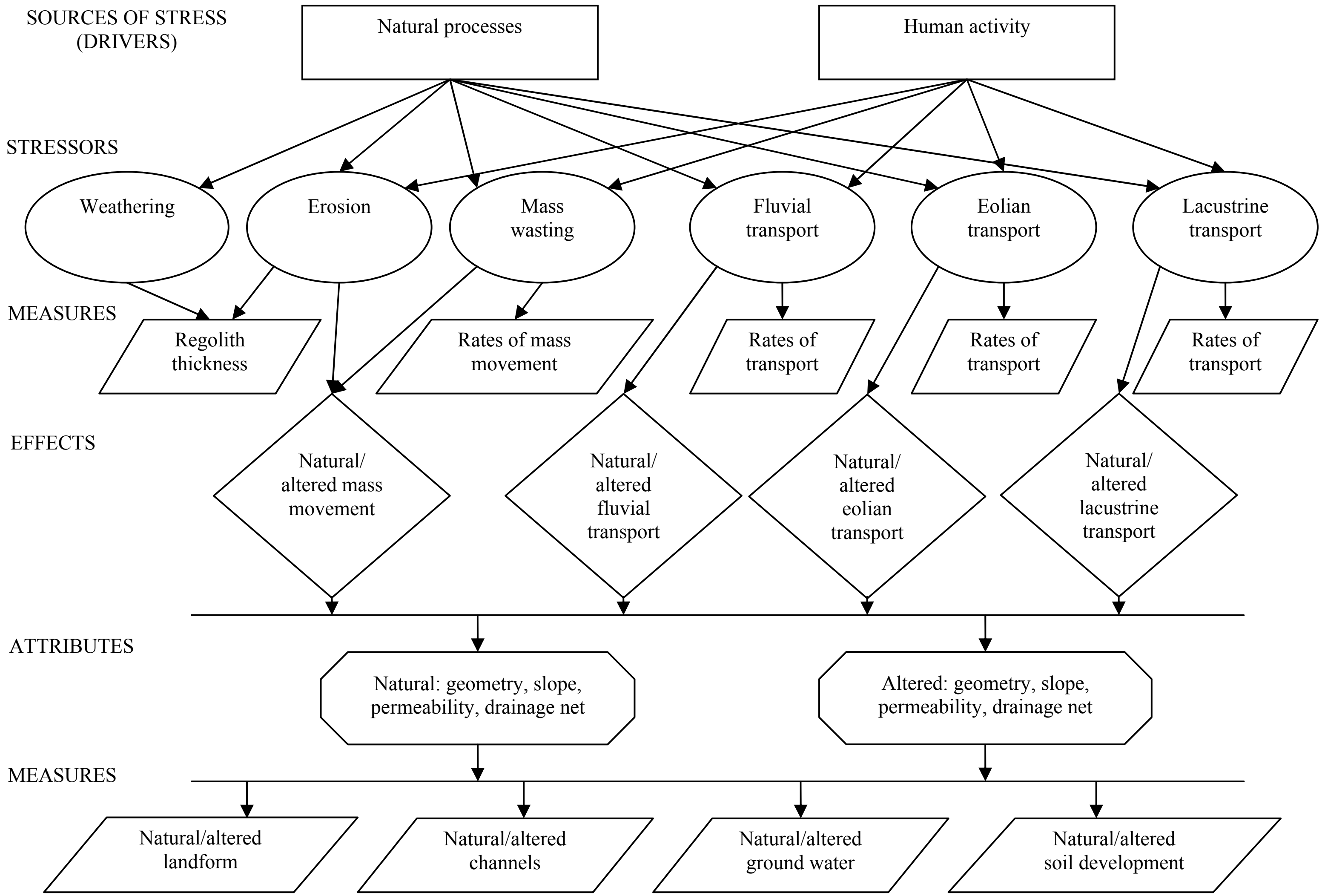


Figure 2.1. Conceptual physical model of the Upper Great Lakes. Model developed for the NPS Great Lakes Inventory and Monitoring Network of Parks to illustrate connections between selected attributes (Vital Signs) and system drivers.

Inland Lakes (Figure 2.2)

General description

Inland lakes are highly valued for the recreational opportunities and aesthetic experiences they provide. They have also attracted scientists for ecosystem studies because of their diversity, relative ease of isolating specific subunits, the ability to conduct ecosystem-level manipulations and to document changes in the global environment (Davis 1981). Because they are sensitive to inputs from the watershed and air sheds, lake ecosystems in most or all areas of the world have likely experienced at least some level of human-induced, ecological change.

To be useful, a conceptual model of a lake ecosystem must be general enough to address the diversity of lake types encountered at even a regional level. The diversity arises in the form of many features of lakes including:

- Trophic status (oligotrophic, eutrophic, dystrophic, etc.)
- Annual mixing pattern (dimictic, polymictic, meromictic)
- Morphometry (depth, volume/area, shoreline development, mean slope, etc.)
- Water Source (stream inlet, groundwater seepage, precipitation)

Responses of lake ecosystems to stressors may vary considerably in duration depending on the type of disturbance and the sub-system affected. Frost et al. (1988) emphasize the importance of recognizing the variations in scale in studying and understanding lake ecosystems. Hence, lakes may show responses on evolutionary time scales (e.g. predator-prey associations) (DeAngelis et al. 1985) to time scales of seconds (e.g. phosphorus cycling) (Norman and Sager 1978). On intermediate scales, exotic crayfish has been shown to alter the littoral community for several years (Lodge and Lorman 1987).

Drivers and stressors

Drivers can be both natural and anthropogenic. Major events such as extreme precipitation and runoff, fire, and erosion are natural drivers that foster increases in nutrient loading or hydrological washout, leading to changes in the lake of varying duration. Lakes are sensitive to events and processes external to their basins. Features of the lake itself, such as basin morphometry, water clarity, and food chain structure, interact with the external influences to modify how change affects the lake ecosystem.

Anthropogenic watershed disturbances such as agriculture, urban development, logging, and fire are major influences on lake ecosystems (Scrimgeour et al. 2001, Garrison and Wakeman 2000). Loss of protective vegetative cover on soil leads to increased loading of nutrients and sediments, which increases growth of phytoplankton and submersed aquatic vegetation.

Shoreline disturbances such as clearing emergent and submersed vegetation and removing woody debris can lead to loss of aquatic habitat, decreased amphibian populations (Woodford and Meyer 2003), reduction in fish growth rates (Schindler et al. 2000), and decreased water quality (Garrison and Wakeman 2000).

Atmospheric deposition of contaminants illustrates the broad extent to which lakes are affected by factors external to the basin. The watershed area for a given lake in most cases is small in comparison to the air shed. Mercury can enter lakes via atmospheric deposition and is a problem in water bodies throughout the Great Lakes region.

Deposition of oxides of sulfur and nitrogen from combustion of fossil fuels causes acidification of lakes. Atmospheric transport may be over great distances or from nearby sources. Acidification of lakes is significant for its broad ranging ecological effects as well as its influence on the methylization of mercury.

Recreation activities are increasingly regarded as a major influence on lake ecosystems. Considerable pressure from fishing and boating can lead to impacts on the age and size structure of fish populations and the food web (Reed-Andersen et al. 2000, Landres et al. 2001, Harig and Bain 1998). Introduction of invasive and exotic species can occur when boats carrying entangled biota are moved from lake to lake (Johnson 2001).

Climate change could become one of the most serious anthropogenic influences on lake ecosystems. An increasing number of scenarios and predictions suggest the effects of climate change on lakes include nearly all communities and processes via altered temperature regimes, hydrologic patterns, and interactions with numerous other stressors. However, Davis et al. (2000) suggest that inland lakes near the Great Lakes may experience less extreme changes because of the moderating effect on temperature of the large water bodies.

Stressors from the above drivers include nutrient and sediment loading, habitat loss, increased loading of toxics, acid deposition, introduction of exotic species, increased recreational pressure, and changes in temperature and precipitation.

Indicators

Indicators that could be monitored for inland lakes include phytoplankton and zooplankton communities, water clarity, littoral community (including submerged aquatic vegetation and periphyton), hyplolimnetic oxygen deficit, fish community, shoreline habitat, organism health, sediment/water quality, annual temperatures, and lake levels.

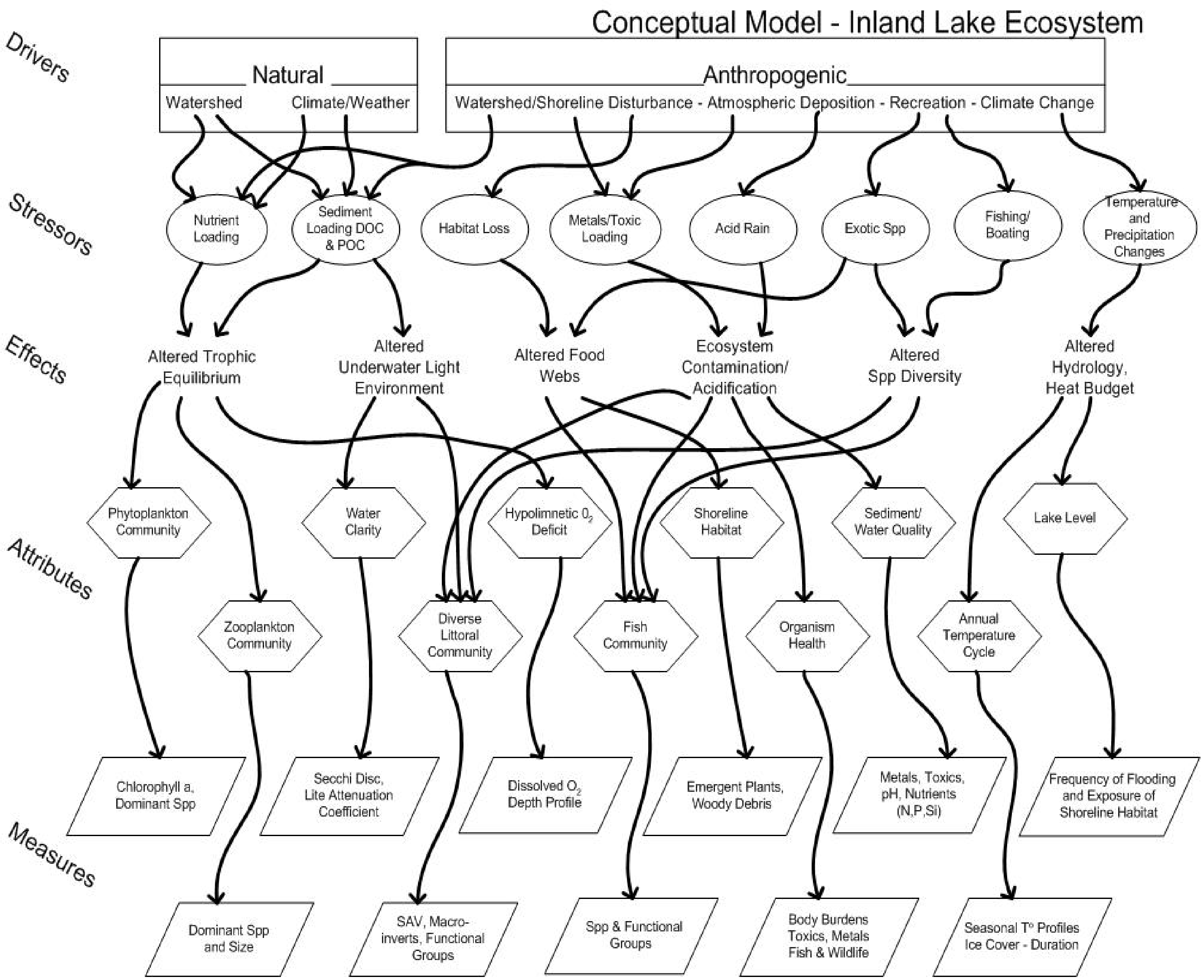


Figure 2.2. Inland lakes conceptual model for the Great Lakes Inventory and Monitoring Network.

Large Rivers (Figure 2.3)

General description

This conceptual model was developed primarily to cover the Mississippi River (MISS) and the St Croix, and Namekagon Rivers (SACN), but it may also be useful for large rivers at other Network parks. Throughout the world, large rivers and tributary networks have been important as highways for human travel and commerce. Hence, humans have built next to them and altered their physical templates and hydraulic dynamics (Welcomme 1985, Dynesius and Nilsson 1994, Galat and Frazier 1996).

Within a basin, as rivers increase in size in the downstream direction, predictable gradients occur in the forces that shape the stream, control the substrate, and provide organic material (Vannote et al. 1980). Large rivers tend to occur at lower elevations than smaller streams within the same basin. They also often have shallower elevation gradients than their tributaries and therefore trap more sediment and have longer water retention times. These conditions, with the exception of local areas where the channel is constricted, generally result in lower water velocities and substrates dominated by finer particles. Under natural conditions, the discharge of a river increases with distance downstream. The predictability of the flow regime of a large river is typically greater than the predictability of its smaller, flashier tributaries (Johnson et al. 1995).

Under natural conditions, the primary sources of energy in a large river, detritus, fine particulate organic material, and attached bacteria, are usually allochthanous, that is, carried downstream by tributaries. The River Continuum Concept (Vannote et al. 1980) holds that local photosynthesis in large rivers is limited by turbid water. However, the presence of dams, floodplains with large backwaters, or large amounts of woody debris in a given large river reach can reset energy processes to conditions more like those that occur in moderate size streams (Ward and Stanford 1983, Junk et al. 1989, Thorp and DeLong 1994, Bayley 1995). Under these conditions, there are increases in in-stream (autochthanous) invertebrate production and energy production through photosynthesis.

In large rivers with substantial floodplains, annual flood pulses have been identified as perhaps the most important hydrologic feature that governs year-to-year changes in ecosystem productivity and possibly diversity (Junk et al. 1989, Ward 1989).

Large rivers frequently exhibit distinctive reach or microhabitat characteristics that are attractive to individual or groups of species (Stalnaker et al. 1989, Montgomery and Buffington 1998). Reaches are frequently distinguished by different vegetation patterns, community types, and habitat assemblages (Lubinski 1993). Microhabitat attractions are often observed during specific life history stages, seasons, or discharge ranges. An especially important characteristic of large rivers is that conditions in their microhabitats change widely with river discharge (Reash 1999). Population changes in response to year-to-year variations in discharge are considered to be an important contributor to riverine biodiversity (Knutson and Klass 1997, Galat et al. 1998).

The flora and fauna of large rivers are adapted to and controlled in large part by the conditions discussed above. It is also important to keep in mind however, that large-scale distribution patterns of many species, terrestrial and aquatic, in the Midwest still reflect zoo-geographic patterns established by glacial land forming processes that occurred thousands of years ago.

Large rivers, within the context of either their tributary networks or even broader spatial scales, function as landscape corridors (Lubinski and Theiling 1999). In this role, they provide ecological services such as removing wastes, and transporting nutrients, sediments and water itself, to systems downstream. The landscape corridor function of large rivers is of special value to migratory birds and fishes. This function may even extend beyond a river's basin, as in the case of the Mississippi and St Croix Rivers, which provide migration corridors between continents for many waterfowl and neo-tropical bird species (Knutson and Klass 1997).

Drivers and stressors

The ecological condition of a large river depends on drivers and stressors that exist at multiple spatial scales (Frissell et al. 1986, Lubinski 1993, Naiman 1998). Drivers that operate at larger spatial scales tend to exert control over longer temporal scales and cycles (Poff and Ward 1990, Naiman 1998). Drivers identified in the Large Rivers model include underlying geology; land cover and use; climate; anthropogenic use of the river, such as for barge traffic, recreation, dredging and filling, creation or removal of barriers, and resource extraction; and point and non-point source pollution.

Indicators

The selection of attributes for monitoring large rivers was based on Karr's (1991) view of primary stream ecosystem elements. The final number of attributes was narrowed to the following four, that could function in an operational monitoring program and would meet the NPS emphasis on trend detection: 1) native species, as measured by composition, abundance, and distribution; 2) water quality, including measures of physical and chemical variables; 3) physiography of the floodplain and channel, as measured by habitat diversity, connectivity, and fluvial dynamics; and 4) flow regime, including discharge, velocity, and water level elevation.

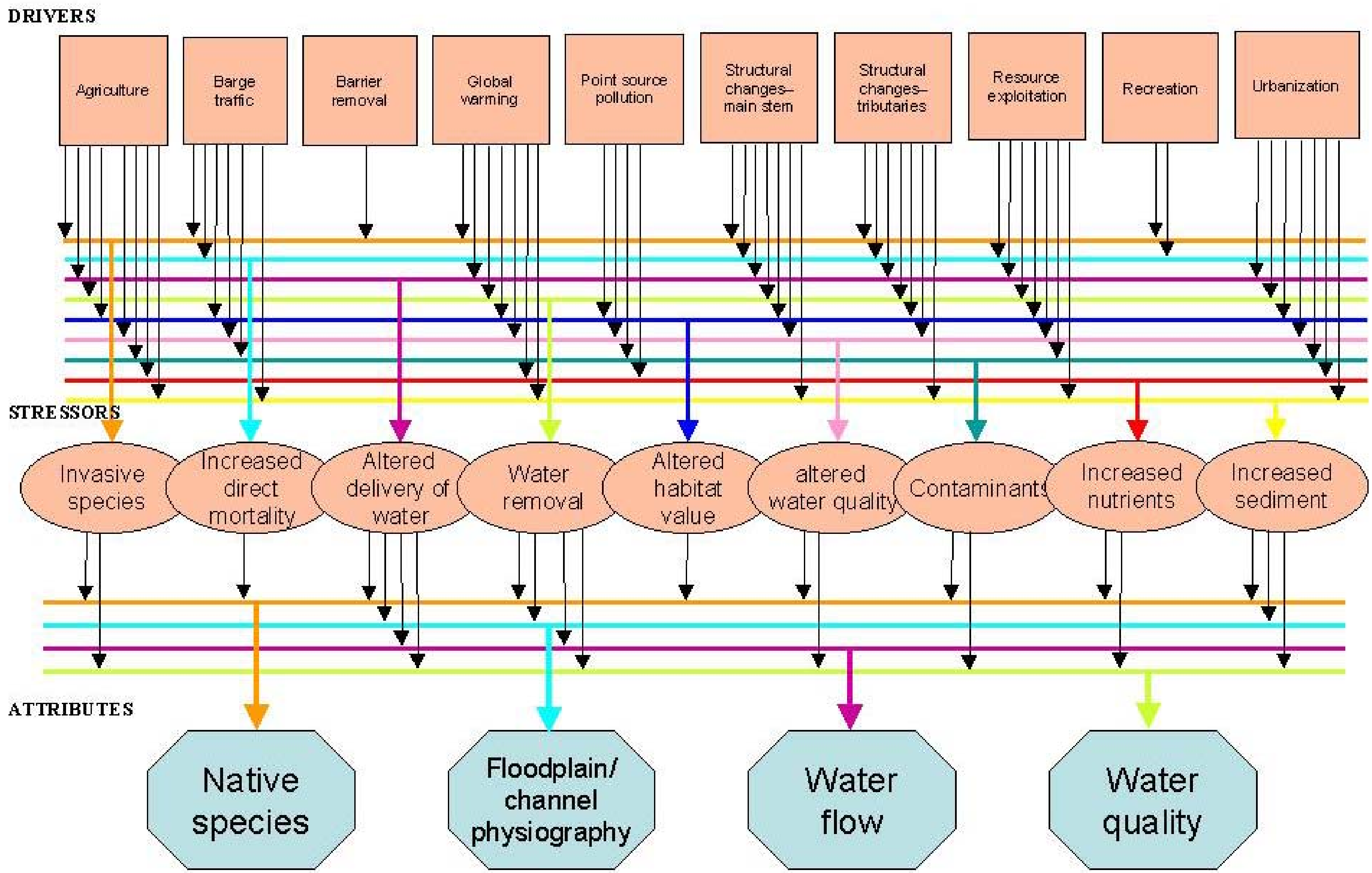


Figure 2.3a. Relationships between anthropogenic drivers, stressors and coarse-level attributes in a large river model. Each stressor (ovals) and attribute (octagons) are represented by thick, colored lines. Connections (probable causal linkages) between drivers (rectangles) and stressors, and between stressors and attributes, are drawn with thin vertical arrows.

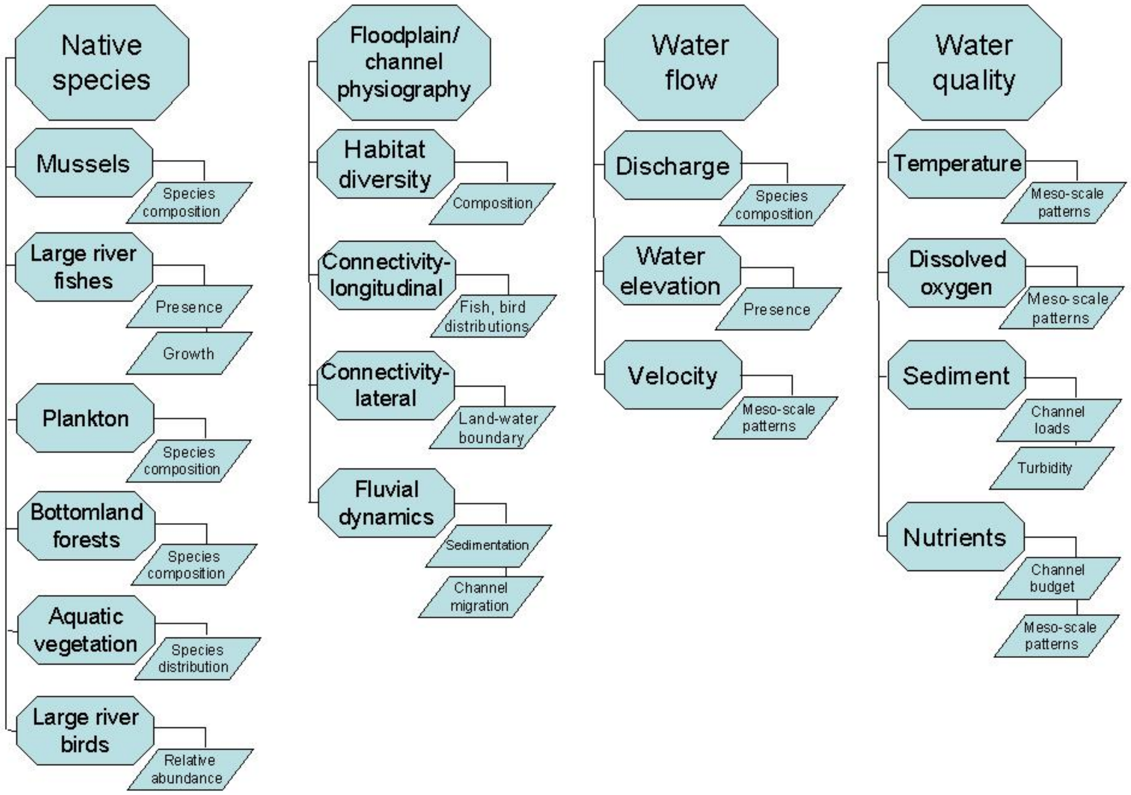


Figure 2.3b. Large river conceptual model relationships between attributes and measures. General attribute categories (larger octagons) are divided into fine-level classes for which specific measures are suggested (parallelograms).

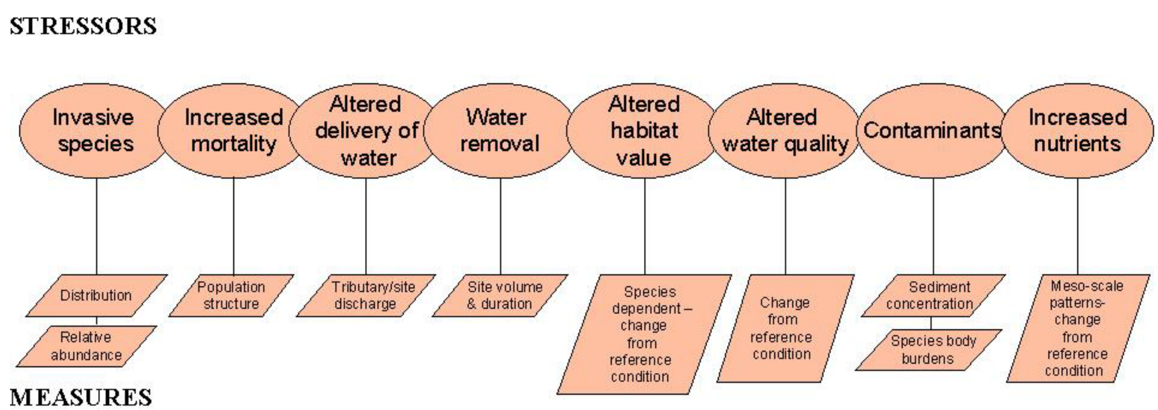


Figure 2.3c. Large river conceptual model relationships between stressors and measures. Direct effects from various stressors (ovals) can be monitored with appropriate measures (parallelograms).

Northern Forests (Figure 2.4)

General description

Forests overall comprise the largest single broad vegetation classification type in the Great Lakes region. In general, forests contain greater biological diversity than any other terrestrial vegetation type (Ricklefs 2001). At the time of European settlement, forests covered about half of the conterminous United States (Spies and Turner 1999). Worldwide, they are important for maintenance of biotic diversity, nutrient cycling, and consumptive and nonconsumptive human activities. Hunter (1999) describes forests and their associated diversity as having ecological, economic, educational, scientific, and spiritual values. Within the Great Lakes Network there are two conifer- and five deciduous-dominated forest types (Barbour et al. 1999). The conifer forests of the Network are the boreal forest and Great Lakes pine forests; the deciduous forest types are the northern hardwoods ecotone, maple-basswood forest, beech- maple forest, oak savanna ecotone, and oak-hickory forest.

Drivers and stressors

In this forest model, the three principle drivers are human development, resource extraction, and natural processes. They exert effects through eight principal stressors as described below:

Fire, insects and disease, herbivory, and climate/weather are important natural stressors. Fire has a profound effect on all terrestrial ecosystems, affecting soils, hydrology, biotic communities, and nutrient availability (DeBano et al. 1998). Maintenance of several forest types requires periodic fire. Insects such as spruce budworm have had widespread effects on forest landscape patterns, community structure, and succession. Climate has a strong influence on ecosystems and is considered the major force defining boundaries of terrestrial biomes (Barbour et al. 1999). Weather can also have profound effects on forests including windthrow and precipitation patterns and events (e.g., ice damage). Larger scale weather events such as El Nino, which is associated with periodic changes in air pressure patterns over portions of the Pacific Ocean, strongly affect all terrestrial ecosystems, including forests. Insects and disease can have major effects on forest composition and structure through defoliation or direct mortality to plants. In boreal systems insects can affect areas equal to or greater than fire (Hall and Moody 1994). Gypsy moths (*Lymantria dispar*) have defoliated large tracts of forest in eastern North America and are moving in to the western Great Lakes region. Although herbivores rarely consume >10 percent of forest vegetation (Ricklefs 2001), herbivore population irruptions have had substantial effects on forest communities. For example, insect outbreaks have defoliated large forested areas and unnaturally high white-tailed deer populations have altered diversity and composition of forest plant communities throughout eastern North America, including the Great Lakes region (Stromayer and Warren 1997, Waller and Alverson 1997).

Important anthropogenic stressors identified for the forest model include pollutant/chemical loading, invasive exotics, habitat loss/fragmentation, harvest, and fire or fire suppression. Pollution, particularly atmospheric pollution, threatens the environment on a global scale (Barbour et al. 1999). Invasive species have altered virtually every ecosystem on earth. It has been estimated that >50,000 exotic species have been introduced to the United States alone (Ricklefs 2001). Human settlement patterns have resulted in loss and fragmentation of forests for thousands of years, leading to pronounced changes in abundance and distribution of forest communities. In northern Wisconsin, timber harvest has resulted in predominantly second growth forests in what was formerly old-growth eastern hemlock and mature northern hardwoods (White and Mladenoff 1994, Spies and Turner 1999). Human-altered landscapes have provided highly desirable habitat for white-tailed deer (e.g. conversion of conifer forest to aspen forest and agricultural fields). This has caused high numbers of deer in many areas of the Great Lakes region and deer have greatly altered forest communities. Human-initiated fires change surface organic materials and nutrient storage (DeBano et al. 1998). Both fire and fire suppression alter forest succession and associated community structure.

Indicators

The stressors and the effects on forested ecosystems described above are best represented by the following 11 indicators (and associated measures):

- Physiology/organism health (histology, reproduction, bioaccumulation, growth rate)
- Abiotic transport and storage (air deposition, contaminant concentration in soils)
- Soil characteristics (erosion, temperature, water storage, structure)
- Habitat mosaic (patch characteristics, connectivity, edge)
- Hydrology (evaporation, transpiration, runoff, infiltration)
- Population demographics (recruitment, survival, dispersal, density)
- Biotic diversity (species composition, relative abundance)
- Succession (regeneration, structure, replacement rate)
- Trophic relations (competition, herbivory, predation)
- Primary production/decomposition (process rates, biomass)
- Soil quality and chemistry (N/P pools, temperature, organic layer)

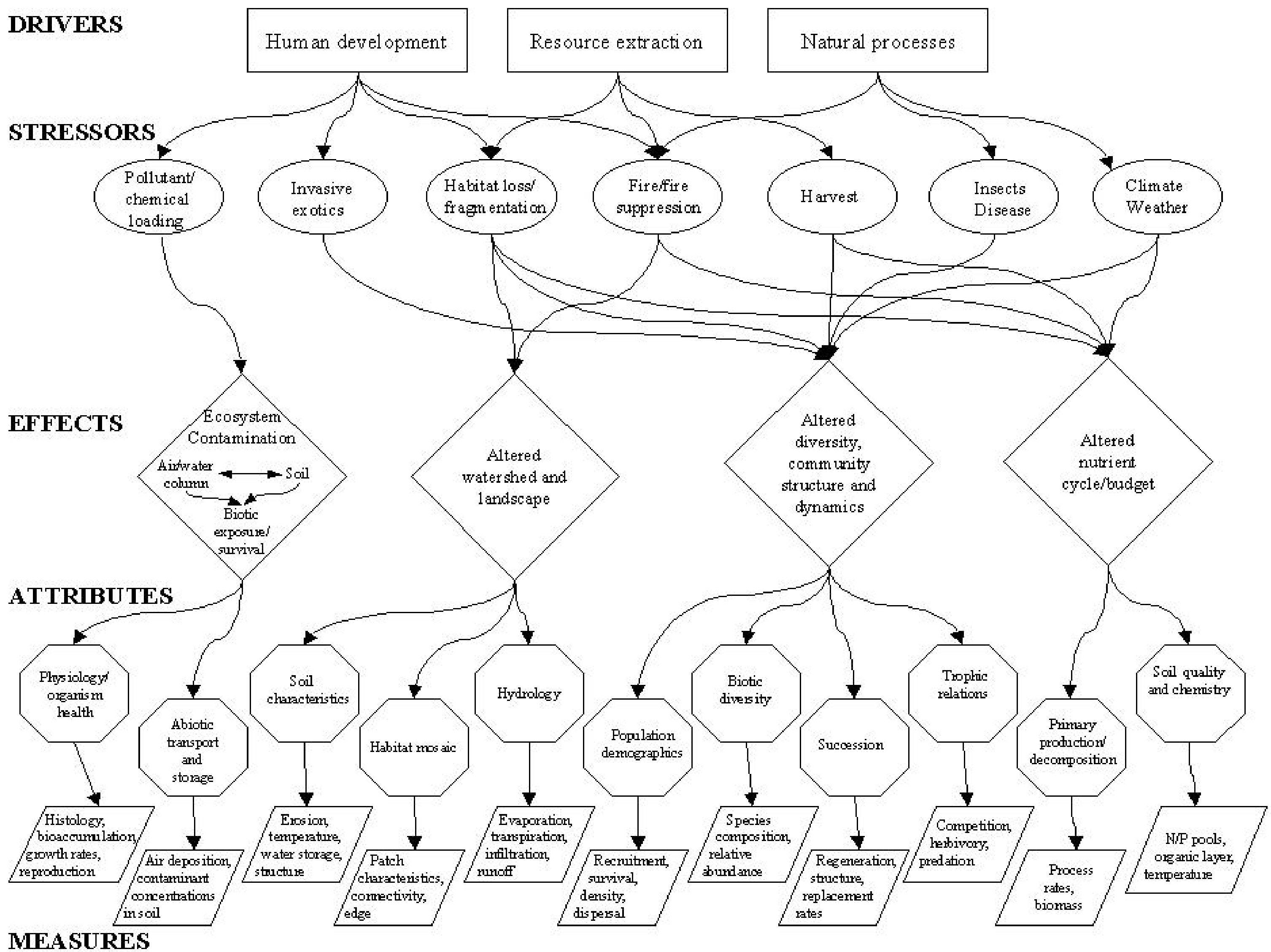


Figure 2.4. Great Lakes forest conceptual model. Model developed for the NPS Great Lakes Inventory and Monitoring Network to illustrate connections between selected attributes (Vital Signs) and system drivers.

Wetlands (Figure 2.5)

General description

The term wetland is a generic descriptor of a wide variety of places, including marsh, wet meadow, swamp, bog, fen, and muskeg. The commonality is the presence of standing water or saturated soils during at least a portion of the growing season. Wetlands exist in places where surface water periodically collects, including depressions surrounded by upland, with or without a drainage system; relatively flat, low-lying areas along major water bodies; shallow portions of large water bodies; and sloped areas below sites of groundwater discharge.

Although wetlands cover a relatively small portion of the world's land surface (approximately 4-6 percent, Mitsch and Gosselink 2000), their ecological and societal values are disproportionately great. Some of these values are flood storage; sediment retention; improvement of water quality; shoreline stabilization; erosion control; habitat for plants, fish, and wildlife; biodiversity reservoir; groundwater recharge; and food web production and export (Maynard and Wilcox 1997, Tiner 1999).

Despite the obvious benefits of wetland environments, they have been extensively modified or destroyed by human activities. In the contiguous United States, approximately 53 percent of all wetlands have been lost in the last two centuries (Mitsch and Gosselink 2000). This widespread destruction of wetlands was accomplished through a variety of activities that altered the hydrology or contaminated the water. Currently, wetlands are the only ecosystem type that is comprehensively regulated across all public and private lands within the United States (National Research Council 1995). The federal Clean Water Act, Section 404, provides protection of wetlands across the nation, but each state has jurisdictional authority to add further requirements.

Drivers and stressors

For the purposes of this model, 'Ecosystem Drivers' refers to the major natural and anthropogenic forces that influence wetland ecosystems. Anthropogenic drivers may disrupt natural processes (e.g., the presence of a harbor or breakwater interrupting the transport of sediments along the shoreline) or occur within the context of natural processes (e.g., the introduction of exotic species during periods of naturally low water levels).

Each ecosystem driver exerts stressors on the ecosystem. Natural stressors to wetland ecosystems include changes in water levels, changes in sediment supply and transport, climate, weather, succession, and biological disturbances. Hydrology is the most important factor in wetland ecosystem maintenance and processes, affecting biogeochemical processes, nutrient cycling and availability, and biological communities (Environment Canada 2002). Addition of sediments to wetlands affects vegetation, water quality, and faunal communities. Transport of sediment along Great Lakes shorelines affects the connectivity of coastal wetlands to direct lake influences. Climate (which is also influenced by anthropogenic activities) affects the floral and faunal communities present in wetlands, as well as water levels. Weather introduces a number of possible disturbance events, such as ice scouring, wave action, and extreme storm events. Succession occurs in wetlands through the accumulation of organic matter, such as peat, and through directional changes in water levels. Several biological stressors may affect wetlands, such as the spread of invasive native plant species (e.g., reed canary grass (*Phalaris arundinacea*)), activities of beaver (*Castor canadensis)*, herbivory (e.g., insects, muskrat (*Ondatra zibethica*), moose (*Alces alces*), waterfowl), and disease.

Anthropogenic stressors to wetland ecosystems include draining, filling, dredging, change in sedimentation, road crossings, shoreline modification, nutrient enrichment, toxic chemicals, water level stabilization, fire suppression, introduction of non-native species, and modification of climate. Many of these stressors are inter-related (e.g., a road crossing may restrict water flow from one part of a wetland to another, hence stabilizing water levels; road crossings increase the chance of introducing exotic plant species) and are due to agriculture and development or urbanization.

Indicators

Physical and chemical indicators include: hydrologic regime, and specifically, water level fluctuation; water chemistry; nutrient balance in water and sediments; primary productivity; decomposition; sediment supply, chemistry, and characteristics; turbidity; and the presence and concentration of toxins.

Indicators at the individual, population and community levels include: organism physiology and health, the concentration of toxins in tissues, population dynamics of wetland-dependent animals, presence and abundance of species especially sensitive to contamination, presence and abundance of exotic species, area covered by different vegetation types (e.g., submergent, emergent), plant and animal community composition, native and total biodiversity, and biotic community indices.

Landscape level indicators include the size, position, and number of wetlands, as well as land use and land characteristics in the vicinity of wetlands.

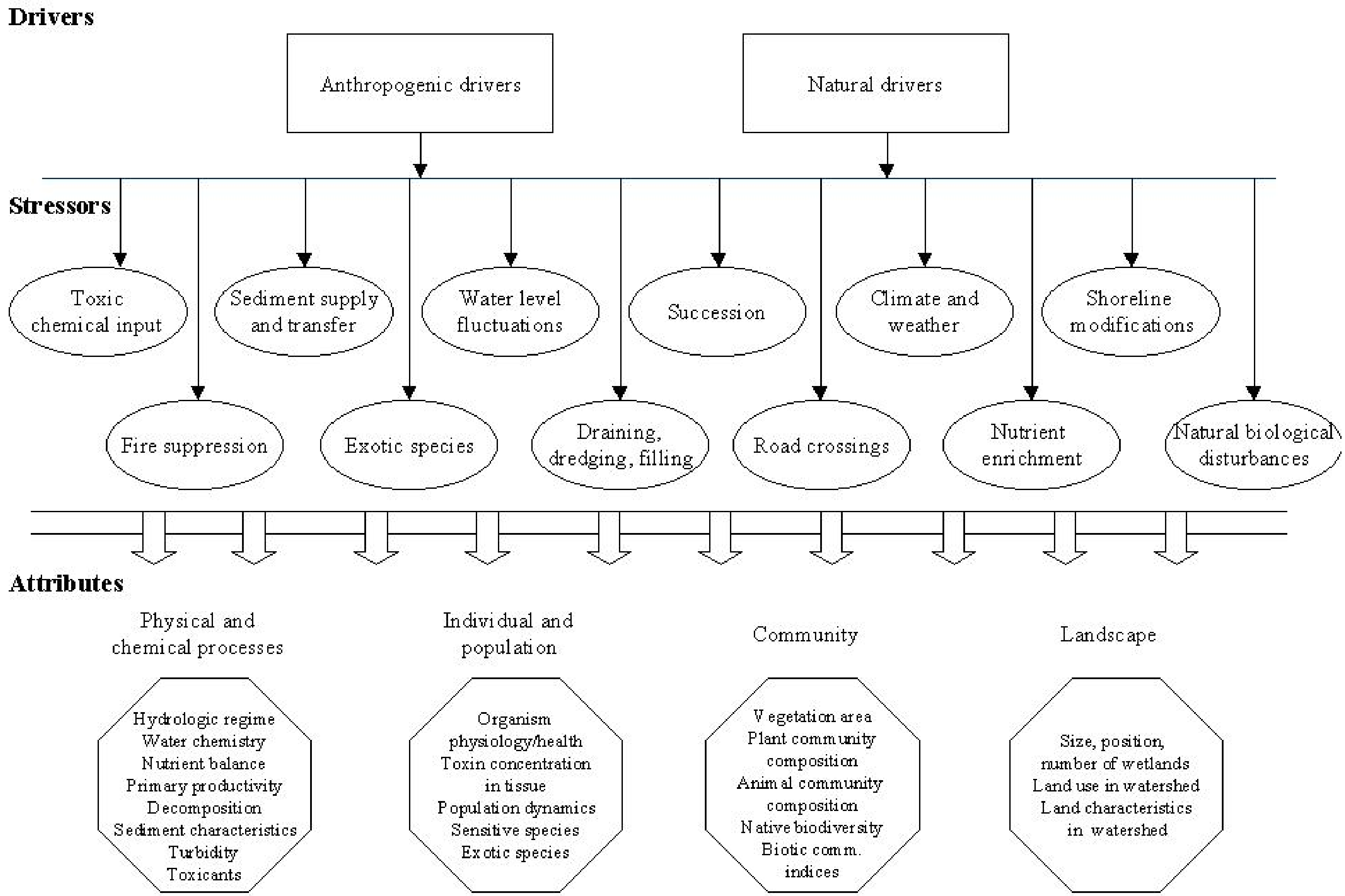


Figure 2.5a. Great Lakes wetland conceptual model. Model developed for the NPS Great Lakes Inventory and Monitoring Network to illustrate connections between system drivers (rectangles) and attributes (octagons).

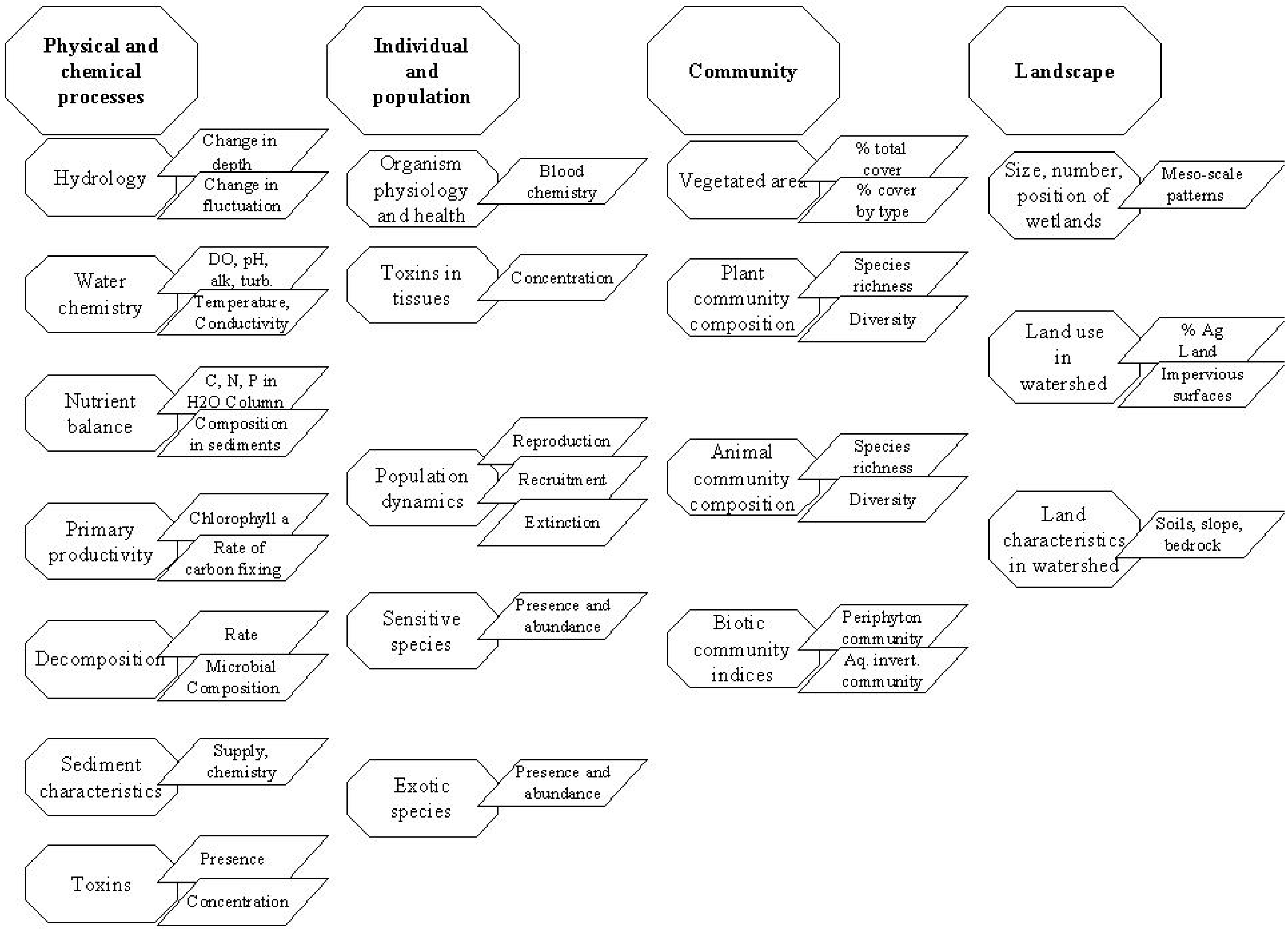


Figure 2.5b. Great Lakes wetland conceptual model attributes and measures. Model developed for the NPS Great Lakes Inventory and Monitoring Network to illustrate subgroups within major attribute categories (octagons) and representative measures of attributes (parallelograms).

USE OF CONCEPTUAL MODELS IN THE GREAT LAKES NETWORK

Conceptual models of the major Great Lakes Network ecosystems served two functions during the development of the program. First, they provided ecological context by summarizing the most important components and processes, putting these components and processes to scale spatially and temporally with illustrations of linkages between components, and by identifying the current and potential threats. Secondly, and as a result of the synthetic process of building the models, they helped us identify, prioritize, and select an initial set of Vital Signs for implementation. In chapter 3 we lay out the process we used for selecting and prioritizing Vital Signs, which included using the models. Refer Table 3.2 for a crosswalk between the selected Vital Signs and the models.

In addition to their value in summarizing information and helping select our Vital Signs, the models will continue to be useful during implementation. The ultimate goal of monitoring is to provide park managers with information to make science-based management decisions and to evaluate the effectiveness of various actions. The models provide a mechanism of communicating the results of monitoring by showing linkages among Vital Signs and the complex interactions of natural and anthropogenic processes. We expect the models will be an invaluable tool to help interpret monitoring results and explore alternative courses of action.

We expect to use the information provided in the conceptual models to develop more refined models or illustrations for specific issues. For example, we have adopted many of the indicators illustrated in Figure 2.6, including Land Cover/ Land Use, Terrestrial Vegetation, Air Quality, Water Quality, Fish Communities, and Trophic Bioaccumulation. Several of these have formed the initial set of Vital Signs being monitored by the Network (see Chapters 4 and 5). Illustrations such as this will be used to present results to other scientists, park managers, and the public in a straightforward and easily understood manor. It serves to make the information more relevant by illustrating how the data are linked to resources. The peer-reviewed conceptual models summarized here, and detailed in Gucciardo et al. (2004), will be the scientific basis for such illustrations.

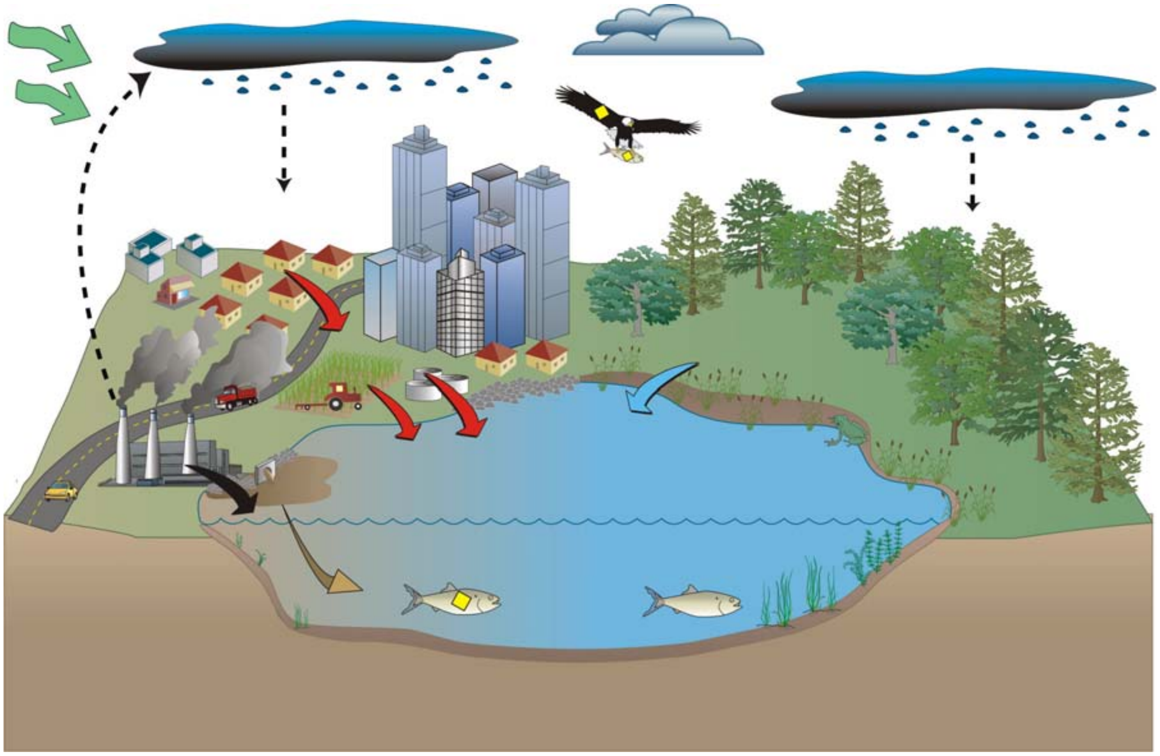


Figure 2.6. Illustration of how weather and land use influence water quality and cause contamination in fish and wildlife. Prevailing weather (green arrows) can drive polluted air over the landscape and deposit contaminants (black dashed arrows) onto water and land. Rainwater runoff across urban, industrial, and agricultural land (red arrows), combined with point-source pollution (black arrow) and sedimentation (brown arrow), will alter water quality. Some contaminants will bioaccumulate in higher trophic levels (yellow diamond in fish and bald eagle). Healthy ground cover in the form of terrestrial and aquatic vegetation can provide a buffer to reduce water pollution (blue arrow).

Chapter 3 – Vital Signs

INTRODUCTION

In September 2001, the Technical Committee laid out a plan for identifying and prioritizing Vital Signs. The plan called for scoping workshops with park staff to generate lists of monitoring issues and questions, development of conceptual models to examine important ecosystem attributes and linkages, focus workshops to get input and review from science peers, and an iterative process of management and science review (Figure 3.1). To maximize efficiency, the Committee expected the monitoring program to emphasize Vital Signs common to all or most of the nine parks. Efficiencies in study design, data collection, data management, and reporting are greatest at the base of the effort pyramid (Figure 3.2) and Network monitoring of these common issues will benefit most from consistent designs that produce comparable data. Conversely, the Committee expected that the least amount of Network effort would go towards single park issues. These issues often require park-specific knowledge, are frequently short-term, and due to economies of scale, are most efficiently conducted by park staff. Nonetheless, some critical single-park monitoring needs may be best met by Network efforts.

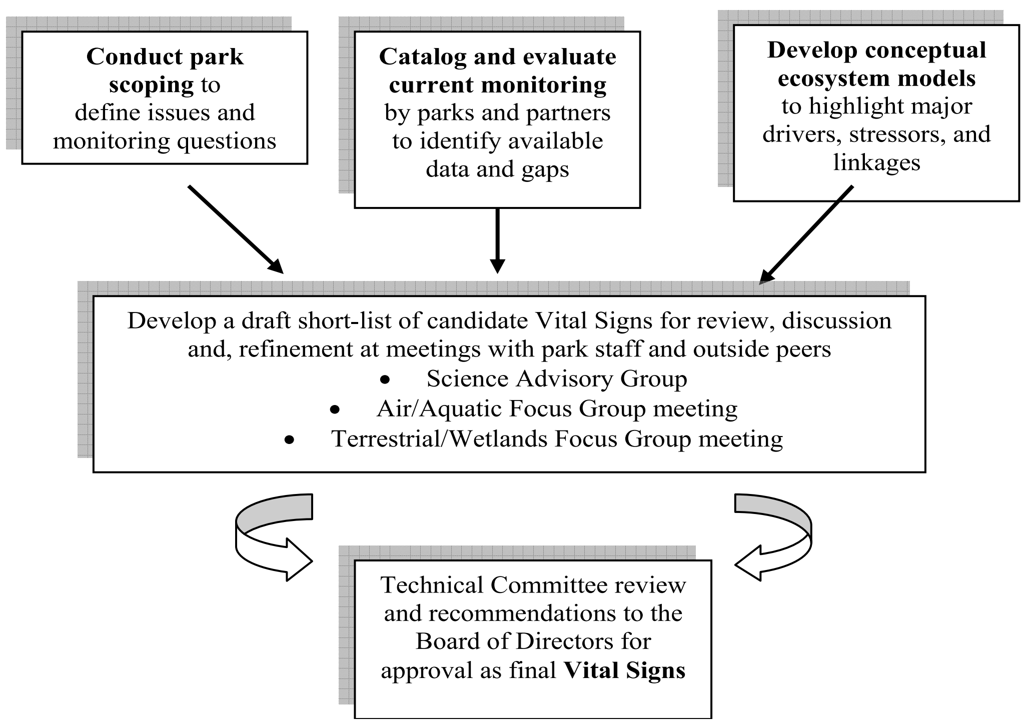


Figure 3.1. The Great Lakes Inventory and Monitoring Network's process of defining issues, gathering information, and drafting a list of candidate indicators for review.

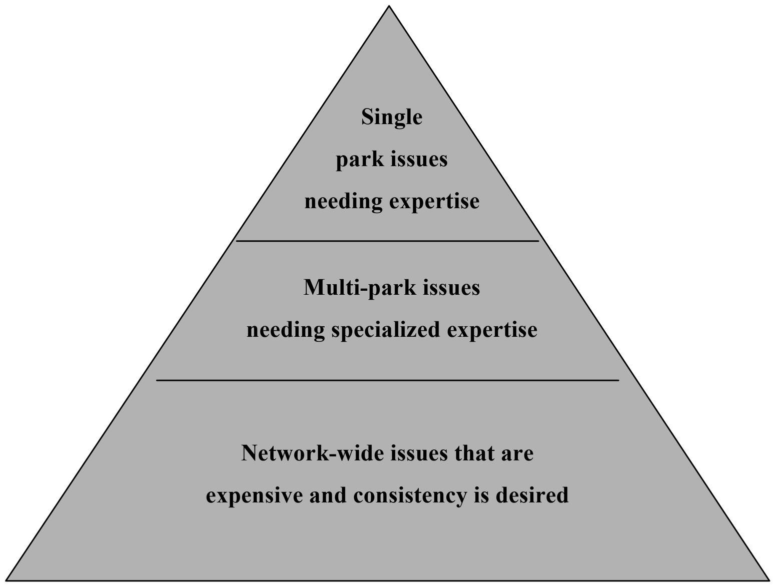


Figure 3.2. Effort pyramid showing the envisioned application of funding and staff time towards monitoring in parks of the Great Lakes Inventory and Monitoring Network.

STEPS TAKEN AND RESULTS

The process for determining Vital Signs was recommended by the Technical Committee and adopted by the Board in September 2002. The Network and partners completed the process via seven steps, which are described briefly below and in more detail in Route (2004):

1. Conducted park scoping workshops and gathered partner information
2. Developed conceptual models of park ecosystems
3. Drafted a list of candidate Vital Signs
4. Refined the candidate list and assigned initial priorities
5. Obtained peer review of the Vital Signs selection process
6. Conducted focus workshops to further refine and score the candidate Vital Signs
7. Prioritized the Vital Signs for Network monitoring

Step 1 - Park Scoping and Information Gathering

The Network began holding park scoping workshops in January of 2002. At these workshops, we engaged 150 park staff and local partners and developed a list of over 200 monitoring issues and 140 monitoring questions (Route 2004, Route 2003). Park scoping helped engage and inform park staff; grounded the process in the parks, where data will be collected and used; and helped Network staff better understand the issues. It also helped identify conceptual modelers and members of the Science Advisory and Focus Groups. Most importantly, the themes and monitoring questions identified at these scoping workshops, together with the conceptual models, formed the basis of the Network's candidate Vital Signs list.

Step 2 - Conceptual Modeling

Following the park scoping workshops, the Network commissioned the development of six conceptual models to examine major ecosystems and processes in the nine parks. The authorship, purpose, and approach to the conceptual models are summarized in Chapter 2. All models were peer-reviewed and published as an in-house technical report (Gucciardo et al. 2004).

Step 3 - Developing a Candidate List

Network staff used the conceptual models, results of park scoping workshops, and information on partner monitoring to draft a list of candidate Vital Signs. Initially, we considered 80 indicators under development by the EPA and Environment Canada for assessing progress towards goals of the Great Lakes Water Quality Agreement (Bertram and Stadler-Salt 2000). Although we used some of the indicators, many did not apply. The draft list of candidate indicators drew most heavily from the park scoping workshops and the conceptual models.

Step 4 - Refining the Candidate List and Assigning Initial Priorities

In October 2003, the Committee adopted criteria and weighting factors for scoring Vital Signs (Table 3.1). Candidate indicators were scored on: Management Significance, Ecological Significance, Measurability/ Sensitivity, and Legal/Policy Mandate. Participants scored them for each criterion in Table 3.1 using a point scale of: very high = 5 points, high = 4 points, medium = 3 points, low = 2 points, very low = 1 point, no value = 0, or unable to score = null. We weighted Management and Ecological Significance equally because ecological integrity is a primary management concern in all national parks (NPS 1991). Management Significance was scored only by park staff, as the use of the monitoring data will be used to make management decisions. Ecological Significance was scored by both parks and Focus Groups; however, Focus Group scores were provided to parks as peer review and not used in final score calculations. The Measurability/Sensitivity criterion was scored only by Focus Groups, because the scientific community generally has the best knowledge of the quantitative measures and ecological linkages critical for judging this criterion. Although 20% seems low for this important criterion, the Committee believed more in-depth information would surface as the Network and its partners analyzed available data and developed protocols. Thus a low weighting at this juncture allowed a Vital Sign to remain viable until more complete information became available. For each criterion, four or five statements were provided to help participants apply the criteria consistently (Table 3.1).

After adopting the criteria, the Committee discussed the candidate list and made minor adjustments. The nine park representatives on the Committee then conducted an initial scoring of the Vital Signs. (Network staff facilitated and participated in discussions but did not score them). The criteria, scoring process, and initial scores were brought to the Board for their concurrence in October 2003. The result was a draft, prioritized list of candidate Vital Signs.

Table 3.1. Four criteria used to score Vital Signs for the Great Lakes Inventory and Monitoring Network by NPS and external scientists who ranked each Vital Sign as very high (5 points), high (4), medium (3), low (2), very low (1), none (0), or null in regards to its importance for monitoring in Network parks. The value "none" equaled zero in calculations, while null was valueless (i.e., no opinion). Adapted from Dale and Beyeler (2001).

1) Management significance (Weight = 40%; scored only by park staff) • Has direct application to one or more management decisions or helps assess management actions. • Helps anticipate or predict impending change in an important resource that could be averted by management action. • Contributes to increased understanding of important resources or ecological processes that ultimately leads to better management. • Data are of high public interest. • Involves resources that are harvested, consumed, endemic, alien, threatened, endangered, or of special concern.
2) Ecological significance (Weight = 40%; scored by both park staff and focus workshop participants; however, focus workshop participant scores were used only as a recommendation to park staff) • Has a strong defensible linkage with the resource it is intended to represent. • The resource or process the attribute represents has high ecological importance based on conceptual models and ecological literature. • The attribute responds to change in a predictable, ecologically explainable manner. • The attribute is integrative over time and provides ecological context or supporting evidence to data from other indicators being monitored by the park or others.
3) Legal/Policy mandate (No weighting - tie breaker; scored only by park staff) • Scored as "5" if mandated by federal law, "4" if by state law or NPS policy, and "n/a" if no laws or mandates apply.
4) Measurability and sensitivity (Weight 20%; scored by focus workshop participants only) • Reliable and effective methods exist for collecting and analyzing data in a consistent and repeatable manner. • The cost of collecting a significant sample is not prohibitive. • Measurements are sensitive to change such that a trend will be apparent if present (high signal to noise ratio). • Human errors in measurement are either low or can be explained.

Step 5 – Review of the Vital Signs Selection Process

In October 2003, Network staff convened a 10-member Science Advisory Group to get peer review of the Network's program with emphasis on the process of choosing and prioritizing Vital Signs. This advisory group includes scientists with many years of experience in long-term ecological monitoring as well as experts in **focal resources** of the Great Lakes and Upper Mississippi River Basins. A list of the SAG members and details on the findings of this meeting are reported by Route (2004).

Prior to the meeting, Network staff provided group members with background information on the program, objectives of the meeting, an outline of the selection process, the candidate Vital Signs list, and the criteria for scoring the Vital Signs. The group felt the Network had a valid process that allowed both managers and scientists sufficient opportunity to scrutinize the Vital Signs. Members of the SAG reviewed the candidate list and had no immediate suggestions for improvement. Each member identified their top “best bets” and those they felt the Network should not monitor. Results of this straw poll were summarized and provided to the parks for consideration in adjusting their scores.

Step 6 - Conducting Focus Workshops

In February of 2004, GLKN held two workshops – one focusing on Vital Signs related to aquatic and air resources, and one focusing on terrestrial and wetland resources. The Air/Aquatic Focus Group consisted of 14 invited scientists and the Terrestrial/ Wetland Focus Group had nine invited scientists. Participants were selected for their knowledge and experience with monitoring natural resources in the region. Prior to each workshop, Network staff provided participants with background information on the program, meeting objectives, web access to the conceptual models, the candidate Vital Signs list, and the criteria for scoring the Vital Signs. At each meeting, participants discussed each Vital Sign and refined and added to the list, but did not delete Vital Signs. Network staff facilitated the meetings and prompted discussion on the ecological significance, measurability, and sensitivity of each Vital Sign.

At each of the two 1½ day-long meetings, participants spent approximately eight hours discussing the Vital Signs and about one hour scoring them. The two groups added nine Vital Signs, combined four others into two, and made some minor name changes. These changes were documented in a summary narrative (Route 2004).

Step 7 – Prioritizing Vital Signs for Network Monitoring

Network staff summarized scores and discussions from the Science Advisory Group and the two focus groups, and then provided the summary to the parks for consideration. Committee members then engaged their park staff with this new information to confirm or adjust their original scores. Six of the nine parks adjusted their scores.

Final weighted scores were then calculated as:

$$\text{Weighted Score} = (MS \times 0.4) + (ES \times 0.4) + (SM \times 0.2)$$

Where: MS = average adjusted park scores for Management Significance
ES = average adjusted park scores for Ecological Significance
SM = average of focus workshop participant scores for Measurability and Sensitivity

The Committee discussed the draft weighted scores in March 2004 and recommended that it advance to the Board without further adjustment. The Board met in April of 2004 and approved the list and priority order (Table 3.2). Following the Vital Signs process, we organized the Vital Signs into the Servicewide “Vital Signs Monitoring Framework” (Table 3.3). This framework illustrates the ecological breadth of the Vital Signs – from species health to geological processes – and facilitates consistency among the NPS’s 32 monitoring networks across the nation.

Table 3.2. Prioritized list of Vital Signs for the GLKN. Scores (5 = very important) reflect input by NPS and outside scientist (see text). Green shows 21 selected for early development.

Vital Signs name	Priority ranking	Models that identified VS as a potential metric[1]
Plant and Animal Exotics	4.3	FO,GL,IL,LR,WE
Core Water Quality Suite	4.3	GL,IL,LR,WE
Terrestrial Plants	4.0	FO,LR
Bird Communities	3.9	FO,IL,LR,WE
Problem Species (White-tailed deer)	3.8	FO
Land Use / Land Cover Coarse Scale	3.8	EP,FO,GL,IL,LR,WE
Threatened & Endangered Species	3.7	
Water Level Fluctuations	3.6	EP,GL,IL,LR,WE
Advanced Water Quality Suite	3.6	GL,IL,LR,WE
Aquatic/Wetland Plant Communities	3.6	GL,IL,LR,WE
Weather, Meteorological Data	3.5	EP,FO,GL,LR,IL,LR,WE
Amphibians & Reptiles (Amphibians)	3.5	IL,LR,WE
Mammal Communities	3.5	FO,WE
Fish Communities	3.5	GL,IL,LR,WE
Land Use / Land Cover Fine Scale	3.5	EP,FO,GL,IL,LR,WE
Trophic Bioaccumulation	3.4	GL,IL,LR,WE
Special Habitats	3.4	FO,LR
Mussels & Snails	3.3	GL,LR
Harvested Species	3.3	FO
Sediment Analysis	3.3	EP,GL,LR,WE
Terrestrial Pests, Pathogens	3.3	FO
Succession (forests, wetlands)	3.2	FO,WE
Toxic Concentrations in Sediments	3.2	GL,IL,LR,WE
Biotic Diversity	3.1	FO,WE
Stream Dynamics	3.1	EP,LR,WE
Trophic Relations	3.0	FO
Air Contaminants	3.0	
Phenology	3.0	FO,IL
Toxic Concentrations in Water	2.9	GL,IL,LR,WE
Terrestrial Invertebrate Communities	2.9	WE
Soils	2.8	FO,WE
Health, Growth and Reproductive Success	2.8	FO,IL,WE
Benthic Invertebrates	2.8	GL,IL,WE
Diatoms	2.7	WE
Aquatic Pathogens	2.7	GL,IL
Air Quality Related Values (AQRV)	2.6	
Algae	2.6	GL,IL,LR,WE
Lichens & Fungi	2.5	
Nutrient Dynamics/Biogeochemistry	2.5	FO,GL,IL,LR,WE
Geological Processes	2.5	EP
Aeolian, Lacustrine Geomorphology	2.5	EP,GL
Primary Productivity	2.5	FO,GL
IBI (index of biotic integrity)	2.4	GL
Zooplankton	2.4	GL,IL
Soundscapes, Light Pollution	2.3	
Freshwater Sponges	2.1	

1= EP= Earth Processes; FO=forests; WE=wetlands; GL=Great Lakes; LR=large rivers; IL=inland lakes

Table 3.3. Vital Signs for nine national parks in the Great Lakes Inventory and Monitoring Network within the NPS National Vital Signs Framework (see text). Green shows those Vital Signs for which the Network will design protocols and fully implement, while yellow indicates those monitored by parks and partners where we intend to collaborate and report on the data.

National Level[1]		Great Lakes Network[2]										
Level 1	**Level 2**	**Vital Sign name**	**APIS**	**GRPO**	**INDU**	**ISRO**	**MISS**	**PIRO**	**SACN**	**SLBE**	**VOYA**
Air and Climate	Air Quality	Air Quality	•	•	•	•	•	•	•	•	•
		Air Quality (AQRV)	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
	Weather	Weather	•	•	•	•	•	•	•	•	•
		Phenology	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Geology and Soils	Geomorphology	Aeolian, Lacustrine Geomorphology	Δ	-	Δ	-	Δ	Δ	Δ	Δ	-
		Geological Processes	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Stream Dynamics	Δ	Δ	Δ	Δ	+	Δ	+	Δ	Δ
	Soil Quality	Soils	+	+	+	+	+	+	+	+	+
		Sediment Analysis	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Water	Hydrology	Water Level Fluctuations	+	+	+	+	+	+	+	+	+
	Water Quality	Core Water Quality Suite	+	+	+	+	+	+	+	+	+
		Advanced Water Quality Suite	+	+	+	+	+	+	+	+	+
		Toxics in Water	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Toxics in Sediments	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Pathogens in Water	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		IBI	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Benthic Inverts	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Freshwater Sponges	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Phytoplankton	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Diatoms	+	-	+	+	+	+	+	+	+
Biological Integrity	Invasive Species	Plant and Animal Exotics	•	•	•	•	•	•	•	•	•
	Infestations and Disease	Terrestrial Pests and Pathogens	+	+	+	+	+	+	+	+	+
	Focal Species or Communities	Aquatic Plant Communities	+	+	+	+	+	+	+	+	+
		Mussels and Snails	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Mammal Communities	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Problem Species (White-tailed deer)	+	+	+	+	+	+	+	+	+
		Special Habitats	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Lichens and Fungi	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Terrestrial Plants	+	+	+	+	+	+	+	+	+
		Fish Communities	+	+	+	+	+	+	+	+	+
		Zooplankton	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Terrestrial Invertebrate Communities	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Amphibians and Reptiles	+	+	+	+	+	+	+	+	+
		Bird Communities	•	•	•	•	•	•	•	•	•
		Biotic Diversity	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
	At-risk Biota	Species Health, Growth and Repoductive Success	+	+	+	+	+	+	+	+	+
		T&E Species	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Human Use	Non-point Source Human Effects	Trophic Bioaccumulation	+	+	+	+	+	+	+	+	+
	Consumptive Use	Harvested Species	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
	Visitor Use	Land use Fine Scale	+	+	+	+	+	+	+	+	+
Ecosystem Pattern and Processes	Land Use and Cover	Land use Coarse Scale	+	+	+	+	+	+	+	+	+
	Soundscape	Soundscapes and Light Pollution	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
	Nutrient Dynamics	Nutrient Dynamics	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Trophic Relations	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
	Productivity	Primary Productivity	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Succession	+	+	+	+	+	+	+	+	+

+ = The Network plans to develop a monitoring protocol or SOP

• = Park or partner monitoring will continue with Network collaboration

Δ = Time and funds are currently not available

– = Not applicable in this park

1 = Level names are from the National Park Service's Vital Signs Ecological Framework

2 = Park acronyms appear in Table 1.4

Short List

In Phase 3 of development, we examined more closely the logistics and costs associated with monitoring each Vital Sign. We also considered that parks would continue to be involved in monitoring their resources and that the Network's role is to monitor a core subset of Vital Signs using statistically robust designs with a centrally-located team approach (see Chapter 1, Goals For Vital Signs Monitoring, provisions #1 and #3; Figure 3.2). We concluded that some important Vital Signs are best left to the parks for monitoring. For example, the Vital Signs 'Threatened and Endangered Species', and 'Harvested Species', will vary greatly across the Network and it would be more efficient for parks to implement them. We also found that some Vital Signs, even if ranked low, could be easily incorporated in to the protocol of a higher ranked Vital Sign. For example, 'Succession' and 'Soils' can be monitored with little additional cost while conducting 'Terrestrial Vegetation' monitoring. Finally, both 'Diatoms' and 'Health, Growth, and Reproductive Success' were originally considered both as individual Vital Signs *and* as part of a suite. We will monitor 'Diatoms' as the biotic component of the 'Advanced Water Quality Suite' and we will monitor the 'Health, Growth, and Reproductive Success' of the species being sampled under the 'Trophic Bioaccumulation' protocol. The final short list for the Network, then, follows the overall prioritization (Table 3.2) with a few adjustments for efficiency and effectiveness (green and yellow highlighting in Tables 3.2 and 3.3).

The short list presented in Table 3.4 represents 21 Vital Signs that we expect to monitor with 16 different protocols. When fully implemented each park would have between 19 and 21 Vital Signs monitored by the Network. This list is our best attempt to determine the Vital Signs that are important across the parks, yet efficient and affordable for the Network to monitor. Nonetheless, the remaining Vital Signs are on a waiting list for consideration as we develop each protocol and gain experience and efficiency in monitoring. Vital Signs such as 'Mammal Communities', 'Sediment Analysis', 'Special Habitats', and 'Phenology' continue to be investigated for potential development either individually or as part of another protocol. Other more mature monitoring programs such as at Channel Islands National Park have found that indicators can often be added in years following initial implementation (G. Davis, personal communication). We hope to be able to incorporate several other Vital Signs in future years.

Table 3.4. Final list of 21 Vital Signs that the Great Lakes Inventory and Monitoring Network plans to begin monitoring during the initial six years – 2006 through 2011. For efficiency, these Vital Signs will be monitored under 16 different protocols.

Protocol	Vital Sign name	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Air Quality	Air Quality	•	•	•	•	•	•	•	•	•
Climate and Weather	Weather	•	•	•	•	•	•	•	•	•
Water Quality (3 protocols - inland lakes, large rivers, and wadeable streams)	Core Water Quality Suite	+	+	+	+	+	+	+	+	+
	Water Level Fluctuations	+	+	+	+	+	+	+	+	+
	Advanced Water Quality Suite	+	+	+	+	+	+	+	+	+
Diatoms	Diatom Community	+	–	+	+	+	+	+	+	+
Wetlands	Aquatic / Wetland Plant Communities	+	+	+	+	+	+	+	+	+
Fish	Fish Communities	+	+	+	+	+	+	+	+	+
Aquatic Nuisance Species (early detection) Exotic Plants (early detection)	Plant and Animal Exotics	•	•	•	•	•	•	•	•	•
Land Use / Land Cover (2 protocols - coarse-scale and fine-scale)	Land Use/Cover Coarse Scale	+	+	+	+	+	+	+	+	+
	Stream Dynamics	Δ	Δ	Δ	Δ	+	Δ	+	Δ	Δ
	Land Use/Cover Fine Scale	+	+	+	+	+	+	+	+	+
Terrestrial Vegetation	Terrestrial Plants	+	+	+	+	+	+	+	+	+
	Problem Species (W.t. deer)	+	+	+	+	+	+	+	+	+
	Terrestrial Pests and Pathogens	+	+	+	+	+	+	+	+	+
	Succession	+	+	+	+	+	+	+	+	+
	Soils	+	+	+	+	+	+	+	+	+
Landbirds	Bird Communities	•	•	•	•	•	•	•	•	•
Bioaccumulative Contaminants	Trophic Bioaccumulation	+	+	+	+	+	+	+	+	+
	Species Health, Growth and Repoductive Success	+	+	+	+	+	+	+	+	+
Amphibians	Amphibians and Reptiles	+	+	+	+	+	+	+	+	+
Total to be monitored (of 21 possible)		**20**	**19**	**20**	**20**	**21**	**20**	**21**	**20**	**20**

+ = The Network plans to develop a monitoring protocol or SOP

• = Park or partner monitoring will continue with Network collaboration

Chapter 4 – Sampling Design

INTRODUCTION

The NPS Inventory and Monitoring Program and other investigators with experience designing comprehensive and multidisciplinary monitoring efforts (e.g., Schreuder et al. 2004, Ringold et al. 2003) argue that individual protocols should be linked spatially, ecologically, and statistically. In an effort to integrate protocols, we began development of 10 protocols (Table 4.1) with a multidisciplinary team of university, USGS, and NPS scientists. We elected to begin with these 10 protocols, which cover 17 Vital Signs, and: a) span the types of habitats that we expect to monitor (e.g., aquatic, terrestrial, and airborne); b) demonstrate clear ecological linkages and high potential for data integration; and c) force us to consider sampling design at several levels of ecological organization and spatial resolution (e.g., landscape, communities, and species; Table 4.1). These protocols will be implemented over the first two years of the program (2006 and 2007), and additional protocols will be added in the ensuing years (see Chapters 5 and 9).

In this chapter, we present overviews of our efforts to develop an initial set of protocols and provide brief summaries of four of them. We discuss types and components of monitoring designs, underlying concepts, and justifications for the designs we have chosen. We also discuss integration among the protocols and with other monitoring efforts. Definitions of some terms used in this chapter are provided in the glossary (Appendix C) and in Box 4.1; these terms appear in bold upon first use in the text.

Inference-based and Non-random Designs

Monitoring programs should be based on statistically robust sampling designs when possible and should be broadly accepted by the scientific community (Christensen et al. 1996). Most of our protocols will be 'inference-based' so that data can be used to describe the entire park or large portions of it. However, it is sometimes necessary to adopt data collected by others, even if those data are collected at sites that were located in a non-random fashion, or if there was low sampling intensity. For example, NOAA weather stations, EPA air-quality stations, and USGS stream gages are not located randomly, and often too few stations exist to provide the statistical power needed to detect change over time within any given park. Yet, the Network is not able to invest adequate funding to improve substantially on these efforts and we will therefore use these available data to monitor some aspects of ecosystems. Similarly, parks in the Network have collected important data over the years for some Vital Signs and it is desirable to adopt and build on these efforts to maintain continuity. In other cases, management questions dictate that we sample at specific areas such that an inference-based approach is not appropriate. We use the term 'non-random' to describe the Network's use of such directed sampling, use of existing partner data, and adaptation of existing monitoring protocols. Consequently, Vital Signs within the Great Lakes Network will be sampled according to one of the two design types described below.

Inference-based Designs

Most Vital Signs will be monitored under protocols that we write according to NPS standards (Oakley et al. 2003) where we will select sample points **probabilistically** to maximize our ability to make inferences to a larger population. These designs will have a high level of statistical rigor and we will ensure adequate sample intensity by conducting simulation or **power analyses** based on comparable or past data sets. Inference-based designs include those for water quality of large rivers, terrestrial vegetation, and amphibians as well as other Vital Signs in the future.

Non-random Designs

Some Vital Signs will be monitored under protocols that we write according to NPS guidelines (Oakley et al. 2003), but from which we will be unable to make statistical inference to a broader area. These are cases where sampling design is predetermined or substantially modified by existing monitoring efforts or where management questions indicate that we direct our sampling to specified areas. By adopting past methods, even when inferences can not be made to a broader area, we can maintain historical and regional datasets that provide spatial and temporal context for the parks. This includes, for example, maintenance of landbird monitoring data that have been collected in a similar fashion for many years across the Great Lakes region by several agencies. By making slight modifications to these existing protocols and clearly documenting the procedures, we will increase consistency and repeatability. Similarly, we will use a non-random design to monitor specific areas or resources (e.g., a set of lakes) when it is not feasible to sample randomly or desirable to make inference to other areas. In all cases, we will examine the quality and completeness of past data, conduct simulation or power analyses to assess the adequacy of sample size, specify (i.e., qualify) the **sampling domain**, consider improvements of the domain, make the data available for analyses of other Vital Signs, and periodically summarize them. Non-random designs include those for air quality and landbird data that have been collected by parks and partners, weather data from NOAA, and stream gage data from USGS.

Box 4.1. Terms used in Chapter 4 (see also the Glossary in Appendix C).

Alpha (α) – The predetermined threshold of statistical significance in null-hypothesis testing. This threshold is frequently set at 0.01, 0.05, or 0.1. *P*-values less than alpha suggest a phenomenon that would rarely occur by chance alone (e.g., a strong trend, relationship between variables, or difference between groups); tests with *P*-values greater than alpha are deemed 'non-significant.'

a priori – Beforehand; when referring to power analyses, this refers to analyses conducted prior to sampling that use existing data to obtain estimates of variability in the monitored component to either estimate sample sizes needed to detect a desired level of change or determine what amount of change can be detected with a particular sample size (see 'Power,' below).

GRTS – Generalized random tessellation stratified (GRTS) design strategy. This design allocates samples in a spatially balanced manner to either linear systems (e.g., a stream network) or other sampling areas (e.g., forest patches). Also maintains spatial balance with addition or deletion of samples.

Power – The probability that a test will reject a false null hypothesis, or in other words that it will not make a Type II error. Power increases as sample size or effect size (e.g., magnitude of change) increases, variability in the indicator decreases, and as alpha is relaxed (= increased).

Power analysis – A calculation performed to estimate sample sizes needed to detect a desired level of change or determine what amount of change can be detected with a particular sample size. Power is a function of sample size, sample variance, effect size, and alpha; consequently, if any four of these variables are known (or chosen), the fifth can be calculated.

Probabilistic design – A sampling design in which all potential points within the sampling domain have a known probability of being selected for sampling. Selection occurs via some process that randomly selects points.

Sample panel – A group of sample units visited at the same recurring interval. Sampling units (e.g., sites) from the entire population may be subdivided into several panels, each of which may be sampled more or less frequently, depending on the re-visit strategy.

Sampling domain – The area in which samples occur. If sampling locations are randomly selected and have reasonable replication, this corresponds to the area about which inferences can be drawn.

Simple random sampling -- strategy in which the number of total sampling sites is selected from the sampling frame (i.e., domain of interest), such that every point within the target area has the same probability of being selected. The procedure for selecting units must be truly random.

Stratified random sampling – sampling strategy in which the overall domain of interest (i.e., sampling frame) is divided up into mutually exclusive and exhaustive subpopulations called strata, each of which is clearly defined. Each sampling unit is subsequently classified into the appropriate stratum, and then a simple random sample is drawn from each stratum.

Systematic sampling – a sampling algorithm in which the first sampling unit is randomly selected and subsequent units are selected according to a regular (i.e., systematic) pattern (e.g., every *i*th grid cell) (Mendenhall et al. 1971)

Type I error –Incorrect rejection of a null hypothesis that is actually true. For example, it is stated that a trend is detected when, in fact, none exists. When expressed as a probability, it can be symbolized by alpha (α); when expressed as a percentage, it is known as significance level.

Type II error – Failure to reject a false null hypothesis. For example, concluding that no trend (or no trend of a particular magnitude) has occurred, although one actually has.

Table 4.1. Habitats, ecological attributes, and linkages of Vital Signs that will be monitored as part of an initial set of protocols being developed by the Great Lakes Inventory and Monitoring Network.

Protocol	Vital signs being covered	Habitat	Ecological attribute	Ecological linkages between protocols
Air Quality	Air Quality	Air	Chemical and process	Major driver of change affecting each of the other indicators; air quality impacts water quality through wet and dry deposition
Climate and Weather	Weather	Air	Process	Major driver of change that affects each of the other indicators
Land Cover / Land Use Coarse Scale	Land Use Coarse Scale	Aquatic and terrestrial	Landscape	Major driver of each of the other indicators; e.g., land cover affects water runoff, quality of water and air, health of many vertebrate species
Land Cover / Land Use Fine Scale	Land Use Fine Scale, Stream Dynamics	Aquatic and terrestrial	Landscape	Major driver of each of the other indicators; e.g., land cover affects water runoff, quality of water and air, health of many vertebrate species
Terrestrial Vegetation	Terrestrial Plants, Succession, Problem Species (in part), Terrestrial Pests and Pathogens, Soils	Terrestrial	Species, community, and process	Affected by weather patterns, land use, and air quality; potential buffer for water quality; habitat for landbirds
Water Quality for Inland Lakes	Core Water Quality Suite, Advanced Water Quality Suite, Water Levels	Aquatic	Chemical and process	Affected by weather patterns, land use, and air quality; affects amphibians, diatoms, fish, and bioaccumulation of toxics
Water Quality for Large Rivers	Core Water Quality Suite, Advanced Water Quality Suite, Water Flow	Aquatic	Chemical and process	Affected by weather patterns, land use, and air quality; affects amphibians, fish, benthic invertebrates, and bioaccumulation of toxics
Amphibians	Amphibians and Reptiles (in part)	Aquatic and terrestrial	Species and community	Indicators of water quality; may also reflect changes in climate, land use, and land cover; are consumed by birds and other predators
Bioaccumulative Contaminants	Trophic Bioaccumulation; Species Health, Growth and Reproductive Success	Air and aquatic	Process and species	Assess the ecological effects of air- and water-borne toxics that biomagnify in the environment
Landbirds	Bird Communities	Terrestrial	Species and community	Affected by patterns and magnitude of land use, terrestrial vegetation, and climate

DESIGN COMPONENTS AND CONCEPTS

Sampling Domains

One of the essential components of a sampling design is a clear identification of the sampling domain (i.e., the area effectively sampled), including a precise description of the target population. The 'target population' is the ecological resource for which information is desired. The population may be discrete, as in the population of lakes within a park boundary, or continuous, as in a tract of forest land or a length of stream. We used an iterative process that included conceptual models and meetings with park and partner scientists to develop monitoring questions, which, in turn, identified target populations and sampling domains.

The nature of the target population guides the development of a sample design. If the target population is small enough that it can be sampled in its entirety (i.e., a census approach), then statistical inference is not an issue. More often, though, the target population will be large relative to our sampling capabilities, and a representative sample must be selected. Ensuring that a sample is truly representative of the target population is a key consideration in development of GLKN protocols, but this consideration must be balanced against logistics, safety, and cost (Field et al. 2005).

Park boundaries pose a significant challenge to monitoring programs because the stresses imposed on park resources often originate outside of park boundaries. While physical sampling outside the park boundary is often not possible or economically justifiable, the Network will use remotely sensed data to assess changes in land cover and land use not only within park boundaries but also in buffer areas around each park.

Spatial and Temporal Allocation of Samples

Given a large target population, the sampling designs least likely to produce bias are those in which samples are selected probabilistically (Manly 2001, Hayek and Buzas 1997). McDonald (2003) provides terminology to discriminate between the spatial and temporal components of a survey design.The *membership design* describes how sample units are selected spatially, and the *revisit design* describes how often individual units are sampled over time. Many alternative membership designs were considered in the GLKN effort, including simple random, stratified random, and systematic sampling, as well as designs that more strongly accommodate logistical and safety constraints. One design that we have used and plan to use in other, future protocols is the generalized random tessellation stratified (GRTS) design strategy (Stevens and Olsen 2004, 2003). This design allocates samples in a spatially balanced manner to either linear systems (e.g., a stream network) or desired sampling areas (e.g., forest patches on an archipelago or in a Lakeshore). The design allows for iterative addition or deletion of samples, while maintaining spatial balance at several hierarchical spatial scales. Several designs were discarded because of inherent disadvantages (e.g., see Table 4.1 of Jean et al. 2004). For example, when total sample size is small relative to the area sampled, simple random sampling may result in samples that are overly clustered, and by chance alone may mean that certain regions of the target population are not sampled. Stratified random samples have the advantages of increased efficiency and precision, but require that the strata be delineated accurately and persist over time (Stevens and Olsen 1991; D. Stevens, Oregon State University, personal communication).

The revisit design was also a critical consideration for our protocol development (Table 4.2). The choice of revisit design involves tradeoffs among the ability to detect interannual trends, the ability to describe spatial variation in a response variable, and the cost of collecting each sample.

The actual designs used for most of our protocols are one of two variants. In *repeating panel designs*, groups of sample units, or **sample panels**, are revisited at a recurring interval. For example, all river sites at SACN comprise a panel, which will be sampled every other year. We may also be using *split-panel designs* (using two or more revisit designs; McDonald 2003); for example a subset of inland lakes will be sampled for water quality every year at each park, and the remaining lakes may be sampled on a longer rotation (e.g. every 10 years).

In the final analysis, accessibility, sampling cost and safety became critical constraints that were factored into the development of designs for several protocols. Additionally, GLKN staff and park personnel recognized a number of instances where it was important to maintain or create **'index' sites** – sites selected for sampling because they are of particular interest, or because they have a legacy of long-term sampling (which allows us to conduct retrospective analyses). Because the area represented by such index sites is difficult to quantify, index sites will not be combined with probabilistically selected sites in statistical analyses.

Sampling Intensity and Frequency

In general, sample size should be large enough to give a high probability of detecting any changes that are of management or conservation importance, but not unnecessarily large (Fry 1992). To estimate appropriate sample sizes, we performed (or will perform) ***a priori*** power analyses, simulation modeling, or both. *A priori* power analyses are statistical calculations made prior to the initiation of monitoring fieldwork using pre-existing data (Thomas and Krebs 1997). Because these data provide an estimate of the variability in the target indicator, power analyses can be used to estimate the approximate sample size needed to detect a trend of a given magnitude. For power analyses, we used 20% as a minimum level of change that we sought to detect. Most resource managers at our parks felt this detection level was reasonable, and other monitoring programs have adopted this standard as well. We were interested in detecting change in either direction (i.e., whether it were an increase or decrease in the indicator); we thus employed two-tailed tests. We used web-based power calculators and simulation analyses to determine how many sampling locations the Network would need to detect a 20% change between two points in time, in a paired *t*-test framework. In these analyses, the period of time over which the change occurs is not inherently specified. Instead, the temporal period depends on how many years occur between sampling events.

Table 4.2. Monitoring approach for ten protocols being developed by the Great Lakes Inventory and Monitoring Network in 2006 and 2007.

Protocol[1]	Sampling approach	Spatial sampling design	Revisit design and sampling frequency	Domain of inference
Air Quality	Acquire park and partner data	Index sites; stations in and adjacent to each park	No panels; all stations engaged in continuous data collection	Stations will only index interannual change at each site; kriging or field sampling may be used to interpolate to other park areas
Weather and Climate	Acquire park and partner data	Index sites; stations in and adjacent to each park	No panels; all stations engaged in continuous data collection	Stations will only index interannual change at each site; kriging or field sampling may be used to interpolate to other park areas
Land Cover / Land Use Coarse Scale	Satellite imagery	Entire park with larger regional extent for context	complete revisit every 5-7 years	Entire park area, and adjacent areas (watersheds or 10 km buffer)
Land Cover / Land Use Fine Scale	Aerial photography	Entire park with adjacent buffer	Complete revisit every 5-7 years	Entire park and 400 m to 2 km buffer depending on park
Terrestrial Vegetation	Site visits with plots and transects	Grid-based GRTS plus index sites	Entire park, complete revisit every 5 years	Entire park area that is forested, except some smaller islands at ISRO, VOYA and APIS
Water Quality for Inland Lakes	Site visits and acquire partner data	Index sites	Complete revisit, annually, 3x/yr	Individual lakes
Water Quality for Large Rivers	Site visits and acquire partner data	Linear-based GRTS and index sites	Complete revisit, every other year, monthly during open-water season	Mixed, due to use of both randomly selected and index sites
Amphibians	Site visits along roads, or fixed-area searches	Simple random; grid-based and linear GRTS	Ideally, complete revisit, annually. Still being debated.	Pilot work will determine whether road-based or entire park
Bioaccumulative Contaminants	Site visits to sample individuals	Census of nests or colonies; census or random sample of tissue for lab analyses	Complete revisit or repeating-panel; annual to every 2-3 years	Buffers around individual nests (eagles), individual-based areas for other species
Landbirds	Acquire park-collected off-road point data	Points placed systematically along transects	Complete revisit, annually	Historic designs placed transects haphazardly (non-randomly), and thus produce only an index

[1] = See Table 4.1 for a list of Vital Signs being monitored under each protocol.

In addition, to determine how many consecutive sampling events (across years) would be required to detect a 20% change in water-quality variables at each lake in the network, we used analyses (Gerrodette 1993) of root mean-square error using historical data. We are not aware of currently available power analyses that simultaneously incorporate spatial, intra-annual, and interannual variability; one can ask either how many sampling locations are needed, or how many repeat years of sampling are needed to detect a selected level of change.

For complex monitoring designs that may need to account for issues such as detection probability, fixed and random effects, and missing data, simulation modeling can be a particularly useful approach for determining sample size (Eng 2004, Muthén and Muthén 2002, Lukacs, *in prep*.). Simulation modeling employs a mathematical model to virtually repeat the study hundreds or thousands of times, to allow estimation of power essentially by direct measurement (Eng 2004).

Type I versus Type II Errors

As with all scientific hypothesis testing, monitoring programs must weigh the relative costs and benefits of **Type I** versus **Type II errors**, and set **alpha** (α) and **power** ($1 - \beta$) accordingly (Field et al. 2005, Di Stefano 2001, Steidl et al. 1997, Toft and Shea 1983). Scientists traditionally seek to reduce Type I errors and accordingly prefer small alpha levels (Shrader-Frechette and McCoy 1992). In a monitoring program with a strong resource-conservation mandate, however, it may be preferable to employ an early-warning philosophy by increasing alpha and consequently increasing the power to detect differences or trends (Roback and Askins 2005, Sokal and Rohlf 1995, Shrader-Frechette and McCoy 1992).

Accordingly, we have adopted an alpha = 0.10 and power = 0.80, to be able to detect magnitudes of change of ≥ 20%, in agreement with other NPS I&M approaches. Furthermore, we recognize that analyses investigating resource degradation whose results involve $0.20 > \alpha > 0.10$ may merit increased monitoring or experimental research.

For our initial set of protocols, *a priori* power analyses were conducted when possible to determine the approximate sample size needed to detect meaningful (≥ 20%) levels of change. Given our specification of alpha, desired power, and effect size, combined with information on the variance of the response variable in question (obtained from past or comparable monitoring), it was possible to calculate the sample size required to achieve these results. In some cases it was necessary to abandon measurements of highly variable indicators or qualify the resulting data as being useful only for showing the range of variability.

In several instances the program TRENDS (Gerrodette 1993, 1987) was used to perform power analyses to estimate sample sizes. One key decision in any power analysis involves determining the estimate of variance. When assessing power to detect trend across a spatial domain, the coefficient of variation among sampling locations has traditionally been used. Most of the parks, however, are interested in detecting interannual trends in Vital Signs. We acknowledge that TRENDS and most other power analysis programs can handle only very simple designs, and will not give a true indication of power when revisit designs and measurement panels become more complicated. These programs were therefore used as heuristic rather than exact methods for estimating power, by providing a first approximation of required sample sizes. We will use simulation approaches to generate a more accurate estimate of power once an initial data set is obtained.

For analysis of temporal change at a single sampling location, it is more appropriate to use the Root Mean Square (RMS) error derived from a linear regression of response-variable data over time – essentially the coefficient of variation around the regression line (Nur et al. 1999). The RMS has the advantage of addressing an important component of variation – the scatter around the prediction line when a trend is present – and incorporates numerous sources of error, including random measurement error, sampling error, and the inherent variation around an individual observation. With respect to trend analyses, this analysis yields the number of repeat sampling events (i.e., across, not within) years required to detect a significant trend at that sampling location.

RESULTING DESIGNS

For each protocol, we adopted sampling designs that best met the following considerations: ability to answer the monitoring question(s), applicability to the domain(s) of interest, conformity to standards of the discipline, statistical power, comparability of data to regional or national monitoring programs, suitability for retrospective analyses (i.e., ability to incorporate pre-existing, longer-term data), logistical constraints (accessibility), safety, and cost. Each protocol, and often each park, had unique problems and thus no one design fit all applications. The following sections describe key design aspects of four protocols that were pilot-tested in 2006 and will be further tested or ready for implementation in 2007. Protocol Development Summaries are available for these four in Supplemental Document 7. Several other protocols are also under development, and are summarized in Supplemental Document 7, but their sampling designs have not been fully addressed. We envision that the proportion of protocols that utilize probabilistic sampling will continue to increase over time, although in some parks the spatial domain may be limited (e.g., for especially inaccessible or unsafe sites).

Water Quality for Large Rivers

Sample design for the large rivers protocol was derived in part from two established ecological monitoring efforts, the USGS National Water Quality Assessment program (NAWQA) and the EPA's Environmental Monitoring and Assessment program (EMAP). The NAWQA program uses two types of fixed sites: integrator sites, which are located at major confluences of tributaries with the mainstem, and indicator sites, which are believed to represent conditions in relatively homogeneous basins. The EMAP program uses a generalized random-tessellation stratified (GRTS) design that results in a spatially dispersed yet random sample (Stevens and Olsen 2004). The sampling design for GLKN rivers differs from the EMAP and NAWQA approaches in that it uses a combination of randomly-selected and index sites. Selection of random sites involves a GRTS approach, by distributing a target number of sites (derived from power analyses) along the length of the mainstem of the river (Figure 4.1). This approach will be applied across the St. Croix and Namekagon Rivers, within SACN. Power analysis on past data has shown that six randomly selected sites, three each in the upper and lower portions of the riverway, are adequate to meet our criteria for detecting interannual change in most water-quality variables. For separate analyses, index sites will be selected based on recommendations from the multi-agency St. Croix Basin Water Resource Planning Team, which is currently developing a comprehensive monitoring plan for the basin. Based largely on budget considerations, we expect to select five integrator sites along the St. Croix and Namekagon Rivers. Many sites on the Mississippi River within MISS park boundaries are currently monitored by other agencies. We have selected additional index sites at MISS to fill gaps where stretches of the river are not included in monitoring conducted by others.

The randomly selected sites in SACN will allow inference across the mainstem of the entire St. Croix and Namekagon Rivers, within park boundaries. The integrator sites will not allow inference to other areas of the rivers, and data from these sites will be analyzed separately for each site, through time. At MISS, sampling sites were selected to add information to ongoing monitoring programs. Thus, data will again be analyzed separately for each site.

Sampling will alternate yearly between the two large river parks. During each sampling year, the rivers will be sampled nine times during the open water season, approximately monthly, from May to November.

Lotic systems such as large rivers provide a potential challenge, in that the same water that exists at a given point in time will occupy a point downstream at a later point, albeit after mixing, dilution, and dispersion. Hydrologists acknowledge that downstream locations are thus partially dependent upon upstream locations, although upstream locations are not influenced by what happens to water quality downstream of them. However, they also recognize that characteristics of a sampling point's drainage area (i.e., its geology, geomorphology, land use, etc.) will influence the water quality at that sampling point. That is, if the water quality at a downstream location is different from an upstream location, we attribute those water quality differences to the intervening drainage area. As long as the time and distance between the two samples exceeds the residence time or flow rate of the river, then a hydrologist usually expects the samples to be independent of each other. In our work, we are fairly confident that the study design employs independent sampling locations. At SACN, 11 stations are spread over a large drainage area (nearly 7800 sq. mi.), spaced by meaningful distances, such that we expect water-quality results to be independent among stations. Furthermore, the most closely located stations in the design, the three random sites in Lake St. Croix, are located in 3 of 4 separate sub-basins of the lake, and will be sampled in a downstream-to-upstream sequence (reducing the possibility of "replicate" water-quality results).

Water Quality for Inland Lakes

Great Lakes Network parks contain hundreds of inland lakes, with 299 occurring at VOYA alone. In our first attempt to design an inland lake monitoring protocol, we limited our domain of interest by lake size, depth, and accessibility. We defined lakes as waterbodies with a surface area > 1 ha and a maximum depth of > 1 m, to be consistent with definitions used by the federal EPA-EMAP program and others in states of the upper Great Lakes. We also limited our domain to lakes that are accessible via road or trail because many of the lakes at VOYA and ISRO would require two or more days of off-

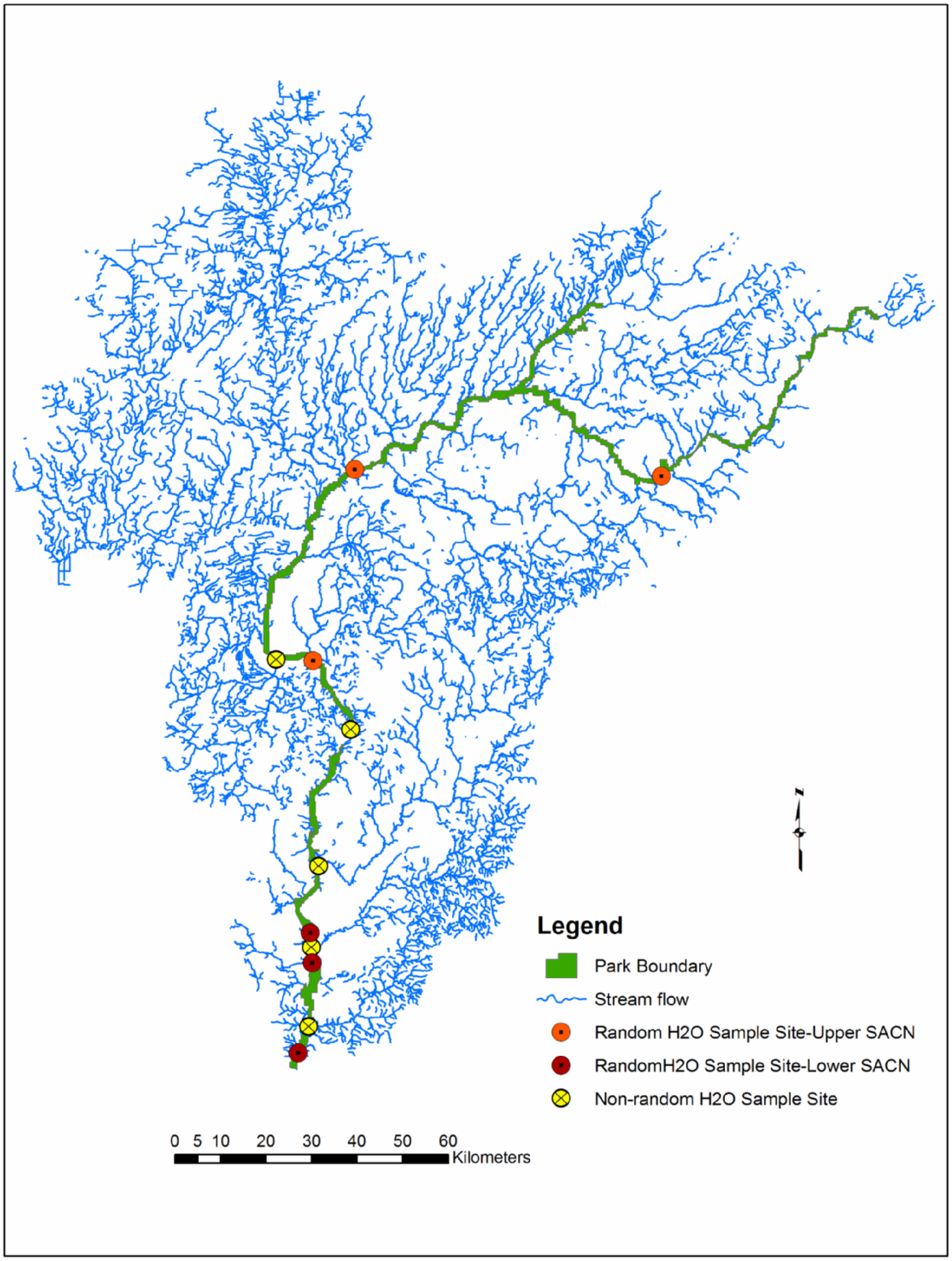


Figure 4.1. Location of randomly selected and index sites for monitoring water quality on the St. Croix and Namekagon Rivers, SACN. Blue lines depict tributaries.

trail back country travel to access. Compounding the access constraints is the need to maintain water samples in cold, dark conditions prior to analysis. Our design resulted in a census of lakes within our defined domain of interest, with all lakes of interest being sampled at some point within the revisit design. Most lakes would have been sampled on a 3-year rotation, with some lakes being sampled on a much longer rotation (e.g. 9 years at VOYA). This approach would not have allowed extrapolation of monitoring results to unsampled lakes.

The most consistent and substantial criticism we received during the peer-review process was in regard to the revisit frequency. Limnologists pointed out that a 3-year rotation could coincide with other cycles, such as El Nino or years of strong fish age classes, and that the amount of time it would take to detect potential trends (27 years in the cases of those lakes sampled on a 9 year rotation) was too great. We are thus revising our design to sample fewer lakes every year.

We are currently working with parks to select lakes within the same size, depth, and accessibility constraints as above. It is likely that the lakes will not be selected randomly, but rather will be selected based on management concerns and amount of historic data. We will strive to select lakes that are spatially dispersed within each park and span a gradient of current water quality conditions and levels of recreational use. When information exists on types of lakes within a park, such as that by Carlisle (2002) for ISRO and Schupp (1992) for VOYA, we will attempt to select lakes from each category.

The frequency of sampling within a year, sample locations, and parameters sampled are designed to allow integration and comparisons with data collected by state and other agencies. The nonrandom selection of lakes in our design, however, will not allow for inferences to lakes other than those sampled. We will analyze data from each lake separately and will use correlational statistics to determine whether parallel trends occur among lakes within a park, across parks, and within the larger region. When similar trends are observed in multiple lakes, additional monitoring may be warranted to determine whether the trend is ubiquitous. Research may also be warranted to determine the cause of the trend.

Amphibians

To be comparable with long-standing amphibian monitoring programs, such as the North American Amphibian Monitoring Program (NAAMP; Weir 2005), Marsh Monitoring Program (MMP; Timmermans et al. 2004), and Amphibian Research and Monitoring Initiative (ARMI), our design will incorporate aspects of each. Our draft protocol recommends a combination of nighttime call surveys (at GRPO, INDU, MISS, PIRO, SACN, SLBE) and daytime visual encounter surveys (at APIS, ISRO, and VOYA).

During the first two years, 2006 and 2007, we will conduct intensive monitoring at a subset of sites at three parks to model detectability for estimating site occupancy (MacKenzie et al. 2004, 2003, 2002) for each species we expect to encounter. In this pilot work, we will also test the effectiveness of parabolic reflector microphones and remote call-recording devices in monitoring and recording calls beyond road corridors to include more remote areas of the parks. In 2008, we will make revisions to the draft protocol with the potential for broadening the monitoring to include more sites and all or a subset of the nine parks.

The sampling design(s) chosen for the nighttime call surveys will depend upon the effectiveness of the parabolic microphones and recording devices, as well upon whether park managers prefer inference to the whole park area or prefer greater sample sizes (and thus, greater precision) at the expense of a reduced (and perhaps biased) sampling domain. Because the initial plan involves limiting nighttime call surveys to roads, the area of inference for the nighttime call surveys will be limited to a buffer around roads equal to the maximum distance at which species can effectively be detected. We recognize, however, that surveys conducted along roads are inherently biased because: a) the roads themselves are not randomly located (i.e., they are often routed around the wetland habitats preferred by many amphibians); b) road-associated stressors (e.g., road salts, noise and dust generated by vehicular traffic, discarded trash, vectors of non-native species) disproportionately affect wetlands at different distances from roads; and c) the road geometry itself creates unequal probabilities of including different sites (e.g., a site might be accessible from portions of two different roads). We will need accurate wetland maps to calculate the probabilities of inclusion (D. Stevens, Oregon State University, personal communication). When this protocol is fully implemented, observers for nighttime surveys will identify up to eleven frog and toad species at up to 30 randomly chosen sites, although we may be unable to select 30 sites in GRPO and APIS. For daytime surveys, the list could include two salamander species as well. In our initial years at each park (during which detectability must be modeled, to correctly understand and interpret trends), sites will be visited three times during each of three sampling periods per year. For broader-scale-analyses (e.g., across the Network), pooling of sites can only occur when sampling with the same method; thus, daytime and night-time sites will be analyzed independently.

Due to the lack of roads at VOYA, ISRO, and APIS, we will conduct daytime surveys using a combination of call surveys, dip-net sweeps, and wetland perimeter searches. The sampling domain will be limited to wetlands within 1000-m buffer areas along the shoreline of Lake Superior, other large lakes, roads, and trails. Defining our domain in this way will allow a reasonably large proportion of these three parks to be sampled. The sampling areas (i.e., park units) will be divided into 6.25-ha (15.4-ac) cells using the GRTS method (Stevens and Olsen 2004). From this initial set, the first 30 cells that contain habitat for wetland-breeding amphibians will be sampled annually. We will use percent area occupied (PAO) as the primary metric and build models of detectability over the first two to three years of the effort. Additional data will include numbers caught or observed within each age class (eggs, metamorphs, adults) per unit effort. Revisit strategies are still being debated (e.g., we will convene an amphibian expert panel in Feb. 2007), though the great interannual variability in amphibian populations (especially in population size, but also in occupancy; L. Bailey, *unpubl. data*) argues for sampling every year.

For both nighttime and daytime amphibian surveys, environmental data such as weather and water quantity and quality are collected as covariates, for use in comparing various models that describe heterogeneity in occupancy.

Bioaccumulative Contaminants

This protocol is designed to monitor concentrations of bioaccumulative contaminants in tissue samples from bald eagles, herring gulls, and one additional species (under development) that inhabit aquatic systems of parks in the Great Lakes Network. The species, and thus strategies for monitoring, will depend on the species' abundance and distributions within each park. We will target legacy and emerging contaminants that are of concern to human and ecosystem health including mercury, lead, PCB's (polychlorinated biphenyls) and DDT (dichlorodiphenyltrichloroethane).

Bald eagle nestlings will be sampled from all known active nests in APIS, MISS, PIRO, SLBE, SACN, VOYA and ISRO by taking up to 11 cm^3 of blood and by plucking four feathers from each nestling. This effort relies on a significant partnership with Clemson University, which is collecting all of the data for parks in Michigan (SLBE, PIRO, and ISRO) and for one park in Minnesota (VOYA; as a control), as part of the Michigan Department of Environmental Quality's Wildlife Contaminant Trend Monitoring Program (Roe et al. 2004). The GLKN will take responsibility for collecting contaminants data from bald eagles at the remaining Network parks that have adequate numbers of eagles (APIS, MISS, and SACN). Both Clemson and GLKN will attempt to gather samples from all active nests in each park (i.e., perform a census). However, the proportion of tissue samples analyzed for contaminants in a given year will depend on per-sample costs, variability in concentrations of the various contaminants, and the number of active nests in each park.

During pilot work in 2006 the GLKN team sampled bald eagle nestlings from 32 of the 37 nests that were known to be active in APIS (n = 8 nests), MISS (n = 10), and SACN (n = 14). Up to two nestlings were captured opportunistically at each nest (i.e., the first and second nestlings that could be most readily captured). We could not sample from five nests because the young were too old to handle safely. Laboratory analysis will be completed on tissue samples from the nestling with the most complete sample (e.g. 11 cm^3 of blood and four feathers), because a full 11 cm^3 of blood is needed for analysis of all analytes. We may not be able to afford laboratory analysis on all samples in future years. If we must limit the number of samples analyzed for contaminants, we will do so using either a simple random, stratified–random, or spatially balanced design. We will stratify only if there is reason to believe that a spatial gradient exists for the contaminants being monitored. Non-analyzed samples will be archived for future use. Previous work by Roe et al. (2004) and Bowerman et al. (2003) show that the number of samples we expect to obtain (i.e., a minimum of 8-12 per park in each year) should be adequate to detect a 20% increase or decrease in concentrations of most contaminants within 10 years for each park, assuming annual sampling.

For herring gulls, we will collect eggs from 13 randomly selected nests in one colony from each of the parks where colonies exist (APIS, ISRO, VOYA, and SLBE). This sampling design follows >20 years of monitoring by the Canadian Wildlife Service (CWS). Eggs will be sent to CWS for analysis of contaminants and inclusion in a larger dataset for monitoring toxics in herring gulls across the Great Lakes region. In two (SLBE and VOYA) of the four parks, a single colony exists for sampling. In one park (ISRO), one colony has been sampled by the CWS for several years and so will be included as an index site. In the remaining park (APIS), one of the two available colonies was selected by park management because of potential disturbance to other colonial species. Because the selection of colonies at these last two parks was not random, we will analyze the data from each colony separately, through time.

Data collected from bald eagles and herring gulls will include age, sex, and physical measurements (eagles only), size and viability of eggs, presence of abnormalities in nestlings or fetuses, and location of nests and colonies. Initially, parks will be revisited every year; however, the revisit rate may be reduced after the first two pilot years, depending on data variability.

QUALITY ASSURANCE

Minimizing Sources of Error

One fundamental goal of monitoring natural resources through time is to ascertain whether a persistent, interannual, directional change is occurring in those resources within the spatial domain of interest. This hinges on the ability to measure the parameter accurately with consistent technique and adequate statistical power (i.e., sufficient sample size given variability in the indicator and desired level of confidence). A well-conceived monitoring program should identify as many of the likely primary sources of noise as possible, and envision strategies to minimize the effects of those sources of error. Broadly speaking, these sources of error fall into three categories: a) observer bias and methodological differences; b) errors in data collection, entry, and management; and c) endogenous variability in the indicator, which is not a true source of error, but is a reason that either sampling intensity or alpha must increase to maintain a given level of power.

Observer bias refers to the consistent effect that a particular observer has on values of an indicator (i.e., higher, lower, more variable, or less variable), without any actual change in the indicator itself. Observer bias can result from minor deviations in methods used, as well as from inherent differences in the ability of various observers to measure resources. To minimize effects of observer bias, we will make use of a combination of the following, depending on the nature of the indicator sampled and the sampling schedule: a) initial training and in some cases, testing, at the beginning of each field season; b) mid-season re-calibration; or c) inter-observer comparisons or explicit incorporation of observer as a covariate in analyses.

Differences in methods used are likely either to introduce bias if the correct technique is not used consistently, or increase variability if a technique is used sporadically. The value of monitoring data can be severely compromised if methods are not clearly defined and followed (Beever et al. 2005, Oakley et al. 2003). The Great Lakes Network intends to minimize the occurrence of deviations in method by adopting clearly defined protocols and standard operating procedures for each monitored indicator (see Chapter 5), following guidelines of Oakley et al. (2003). Pilot field work, in which various data collectors are given the protocols and their results compared, may be used to illustrate where the level of detail is insufficient. Because comparability with other monitoring data sets is necessary to place monitoring results within a broader (regional or national) context, the Network will seek to adopt methods that are broadly accepted as the standard method within a given discipline or taxon for the ecosystems of the region. We have collaborated with university, USGS, and other researchers and monitoring experts in the writing and peer-review of the protocols presented in Chapter 5 to ensure that robust, widely accepted methods are employed.

The second main source of error is also human derived, and involves error in data collection, data transcription (or processing or data entry), and data management. We will address this potential source of error through a QA/QC process throughout the monitoring, as detailed in Chapters 6 and 7.

Finally, the ability to detect interannual trends in a given indicator is complicated by endogenous variability in the indicator itself (i.e., process variation). Examples of this include interannual cycles in mammals, such as the lynx-hare, moose-wolf, and microtine population cycles, and weather patterns, such as Pacific decadal oscillations, El Niño southern oscillations, and others. One approach for irruptive, cyclic, or otherwise highly variable indicators is to calculate process variability (i.e., the variance of the variance estimate over time) and the probability of conformity (that the latest observation is from the previously described distribution) (E. Rexstad, Institute of Arctic Biology and University of Alaska - Fairbanks, *personal communication*). Although this alternative approach can accommodate highly variable indicator values, it still would require longer-term data sets to obtain the same confidence in a trend than what would be required by a less variable indicator.

Strategies to Improve Effectiveness of Designs

In some cases, pilot testing may be conducted in the initial year(s) of a protocol. Reasons for conducting pilot work include documenting new methods and acquiring knowledge about park logistics, which are often difficult to ascertain without experience. One example in which pilot testing is warranted occurs in the amphibian monitoring, in which the use of parabolic reflectors is recommended to extend the area sampled, yet the method is not well documented. Duration of listening at each sampling station is also not universally agreed upon, and represents a compromise between the goals of maximizing detectability at each stop, maximizing the number of stops visited each evening, and completing surveys each night during the appropriate temporal window.

During pilot testing of any protocol, we will explore trade-offs between statistical power and Type I errors, and the value of increasing the number of visits per site versus increasing the number of sites, given restricted budgets. For certain sampling strategies (e.g., amphibians) we will adaptively refine the number of sites and re-visits made, based on an analysis of the data from pilot studies.

Using simulation analyses, Field et al. (2005) explored various aspects of allocating a limited monitoring budget to either the establishment of more sampling locations or re-visiting already established sites, to detect bird species. In cases where detectability is a known source of confounding, we will seek to employ the methods of Field et al. (2005) to make the best use of limited budget yet provide statistically powerful results and defensible interpretations.

Finally, whenever possible, we will ask quantitative ecologists from other networks to peer-review early drafts of our sampling designs in addition to collaborating with disciplinary experts during protocol development.

INTEGRATION

Integration of the various Vital Signs will occur during the design, data collection, data management, data analysis, and reporting phases of the program. This integration will occur within individual protocols, among protocols, and between this Network and other partner programs. Several of our protocols are designed to simultaneously monitor numerous variables from more than one Vital Sign (Table 4.1), such that they will be sampled at the same place (co-location) and time (co-sampling). For example, under the terrestrial vegetation protocol we expect to monitor ungulate browse, forest pests and pathogens, soils, and several metrics of forest structure, composition, and succession. Hence, forest pests and pathogens can be linked to data on forest composition and structure or soil type to provide a more holistic, integrated assessment of a given Vital Sign. Furthermore, we will integrate among protocols where possible, especially in analysis and interpretation of monitoring results. We will acquire remotely sensed data for the land cover/land use protocols to coincide temporally with data collection on terrestrial vegetation plots. The plot data will help ground-truth the remote sensing products and directly link the two data sets.

Integration will also occur between the Network's monitoring and other national and regional monitoring programs when it is scientifically valid to do so. Amphibians and landbirds, for example, will be monitored in such a way that statistically robust results are obtained for each park, yet the data are comparable with other national (e.g., NAAMP) and regional (MMP) programs. Some of these programs have accumulated > 20 years of data at > 1,000 sites around the Great Lakes, and include sites within GLKN parks. By designing protocols to collect comparable data, we will put the parks' data into a regional context, at least for a subset of response variables and spatio-temporal domains.

Similarly, water-quality monitoring for lakes and rivers will include an initial coring of bottom sediments to provide a historical record of diatom communities. Because the sensitivity and tolerance of diatoms to environmental variables – including nutrients, organic pollutants, pesticides, heavy metals, salinity (and major ion chemistry), pH, alkalinity, light, temperature, substrate, and depth – are known to vary among species (Battarbee et al. 2001), analysis of preserved diatom communities facilitates inference of past water quality. Comparing the current composition of diatom communities, which provide an integration of water quality over the short-term, to the species compositions 150-200 years ago allows us to determine whether the current conditions are within of the range of natural variability. Such information will also help the parks assess desired conditions based on the historical record.

The NPS guidelines for developing an integrated monitoring program encourage co-location of sampling sites (NPS 2003). While co-location is planned across Vital Signs, our initial protocols are not well suited to co-location because they do not exhibit spatial overlap (e.g., aquatic vs. terrestrial vs. atmospheric domains). However, sample sites selected for terrestrial vegetation and water quality, are expected to serve as 'base' sites for future monitoring protocols.

Co-location of sites has its drawbacks, however. For example, a given plot may be visited only once every five years for monitoring of terrestrial vegetation, but if co-location is forced, during the intervening years it might be visited annually by different teams to monitor breeding birds, small mammals, and deer browse. If care is not taken to limit the effects of each monitoring team's visit, the monitoring could show change in the vegetation due solely to the disturbance imposed by the sampling teams (*sensu* Paquin 2004 and Eckrich and Holmquist 2000). Additionally, co-location assumes that the same points are equally valid to sample the various target domains for each of the monitoring programs – an assumption that may not always hold. For the above reasons, we did not force co-location for protocols; however, by developing key protocols first, we increase the likelihood for co-location, if appropriate. Those developing new protocols will have, as their first option, a set of probabilistically chosen sites or plots to use. The choice of whether to adopt these sites will depend on: a) whether it is ecologically appropriate for the metrics being monitored, b) whether it is statistically appropriate (in terms of sample size and spatial allocation), and c) whether it will affect the quality of other data being collected at those locations.

In addition to integration in the field, we will integrate data analytically. The conceptual models that provide the linkage among Vital Signs (Gucciardo et al. 2004) were based on known or proposed linkages among factors that operate across spatial and temporal scales. Given the data collected across protocols, we can assess the presence and strength of these relationships using a diversity of statistical techniques, ranging from simple correlations to structural equation models. It must be noted, however, that the primary goal of the protocols was to develop statistically sound monitoring for long-term change detection; tests of causality would require a very different sampling design. That stated, it is still feasible to use GIS-based analyses, simple linear models, and more advanced techniques such as multivariate analyses (e.g., canonical correspondence, redundancy analyses, and classification and regression trees (CART); McCune and Grace 2002), structural equation modeling (SEM), and Bayesian approaches to quantify relationships noted in the GLKN conceptual models. These statistical approaches are described more fully in Chapter 7.

Chapter 5 – Sampling Protocols

The development and implementation of protocols and standard operating procedures will take several years. We expect to implement 16 protocols by 2009 (Table 5.1) and we have thus far completed Protocol Development Summaries (PDS) for 12 of these planned protocols (Supplemental Document 7). Each PDS provides a summary of the justification, objectives, monitoring questions, basic approach for monitoring, and development schedule. In several cases, Vital Signs have been bundled in to a single protocol for efficient monitoring.

The content of all protocols will closely follow recommendations of Oakley et al. (2003). Each protocol will be a stand-alone document that will be attached as a supplement to this monitoring plan.

As a quick reference, we have summarized the initial protocols in Table 5.2. The objectives and questions are spelled out in more detail in the PDS documents and will be refined even further in the completed protocols. Objectives and questions evolve and become more refined as each protocol is developed because additional information may be uncovered, past data analyzed, and logistical and financial constraints better understood. Each protocol is being developed by a lead investigator from the Network and a subject-matter expert from a university or other federal agency. Our multi-disciplinary team approach to developing several protocols was further explained in Chapter 4 as part of the overall design of the program.

In summer 2006 we implemented five protocols after in-house and external peer review. These initial protocols were: water quality of large rivers, water quality of inland lakes, diatoms, amphibians, and bioaccumulative contaminants. The methods for each protocol appear sound though at least one protocol will undergo major change for 2007 (inland lakes), one is still provisional pending data analysis (amphibians), and an additional species must be adopted for bioaccumulative contaminants to expand this program to two more parks.

In summer 2007 we will implement three more protocols in the field: terrestrial plants, land birds, and both coarse and fine-scale land cover/land use. We also expect to implement the climate/weather protocol, which primarily involves mining data from partner programs and making it readily accessible. This later protocol is awaiting data mining efforts that are occurring at a national scale.

We have not predicted protocol development beyond 2009, although we will continue to consider how to add Vital Signs efficiently and effectively to these protocols and/or develop new protocols if time and funding permit.

Table 5.1. Development and implementation schedule for 16 protocols encompassing 21 Vital Signs selected for monitoring by the Great Lakes Inventory and Monitoring Network.

Protocol	PDS[1]	Vital Sign	Year[2] 2006	2007	2008	2009
Climate and Weather	YES	Weather	DB	**X**		
Air Quality	YES	Air Quality	DB	DB	**X**	
Water Quality - Inland Lakes - Large Rivers	YES (2)	Core Water Quality Suite	x	x	**X**	
		Water Level Fluctuations	x	x	**X**	
		Advanced Water Quality Suite	x	x	**X**	
Diatoms	YES	Diatoms	x	x	**X**	
Water Quality - Wadeable Streams	YES	Core Water Quality Suite	PD	PD	**X**	
		Water Level Fluctuations	PD	PD	**X**	
		Advanced Water Quality Suite	PD	PD	**X**	
Fish	NO	Fish Communities		PD	PD	x
Aquatic Nuisance Species	NO	Plant and Animal Exotics	PD	PD	x	**X**
Invasive Plants	NO		PD	PD	x	**X**
Wetlands	NO	Aquatic and Wetland Plant Communities		PD	PD	x
Land Cover/Land Use - Coarse Scale - Fine Scale	YES (2)	Land Cover/Use Coarse Scale	PD	x	**X**	
		Land Cover/Use Fine Scale	PD	x	**X**	
		Stream Dynamics	PD	x	**X**	
Terrestrial Vegetation	YES	Terrestrial Plants	PD	x	**X**	
		Problem Species	PD	x	**X**	
		Terrestrial Pests and Pathogens	PD	x	**X**	
		Succession	PD	x	**X**	
		Soils	PD	x	**X**	
Landbirds	YES	Bird Communities	PD	x	**X**	
Bioaccumulative Contaminants	YES	Trophic Bioaccumulation	x	x	**X**	
		Species Health, Growth and Reproductive Success	x	x	**X**	
Amphibians	YES	Amphibians and Reptiles	x	x	**X**	

1 = Protocol Development Summary. If YES, then a PDS is completed and included in Supplemental Document 7.
2 = DB = database development; PD = protocol development; x = pilot year; X = full implementation.

Table 5.2. Vital Signs, objectives, and some monitoring questions for 12 protocols currently being developed for implementation by the Great Lakes Network between 2006 and 2009 (see Supplemental Document 7 for further details). We expect to add four more protocols in future years (Table 5.1).

Protocol	Vital Sign(s)	Objective	Monitoring Questions
Climate and Weather	• Weather	Provide baseline data and continuously updated data sets to facilitate the detection of regional climatic change in the western Great Lakes region and contribute to an understanding of this driver on other Vital Signs and ecosystems.	o Has the climate of the western Great Lakes region changed significantly from that of past decades or past centuries? o Do these changes in climate warrant specific research or management actions to monitor or predict their effects on natural resources and other Vital Signs?
Air Quality	• Air Quality	Acquire, archive, analyze, and report on the air quality data collected by national and state agencies across the Great Lakes Network to track absolute changes as well as contribute to an understanding of this stressor on other Vital Signs and ecosystems.	o Does deposition of target airborne contaminants change through time? o What are the changes in air quality over time? o Do changes in air quality vary among parks within the Network?
Water Quality (3 protocols) • Large Rivers • Inland Lakes • Wadeable Streams	• Core Water Quality Suite • Advanced Water Quality Suite • Water Level Fluctuations • Benthic Invertebrates (wadeable streams)	Monitor water quality using methods comparable to state and national monitoring efforts such that trends will be detected. Compare trends in parks' waterbodies with trends occurring at broader spatial scales.	o What is the direction and magnitude of change of select water quality variables in individual waterbodies? o Are similar ecological trends occurring across the park, across all GLKN parks, across the region? o What is the direction and magnitude of change in select biotic indicator taxa?
Diatoms	• Diatoms • Advanced Water Quality Suite	Monitor diatom species composition in select waterbodies to contribute to an understanding of water quality changes over time.	o What is the ecological status of this lake in relation to historical (last 150 years) environmental change noted in regional sediment cores? o What is the direction and magnitude of change in select water quality variables in individual waterbodies? o Are similar trends occurring across the park, across all GLKN parks, or across the region?

Table 5.2. Protocol objectives and monitoring questions, continued.

Protocol	Vital Sign(s)	Objective	Monitoring Questions
Land Cover/Land Use (2 protocols) • Coarse Scale • Fine Scale	• Land Cover/Use Coarse Scale • Land Cover/Use Fine Scale	Monitor changes in land cover and land use at several scales to document absolute changes, as well as to provide context for analysis of results of other Vital Signs monitoring.	o What are the changes in area and shape in urban, agricultural, and other areas dominated by human land use within a defined monitoring region for each park? o How has human population density, measured either by population or an index such as buildings, changed in each monitoring region? o What are the changes in select variables (e.g., road density, impervious surface, amount of wetland, habitat fragmentation) within and adjacent to each park?
Terrestrial Vegetation	• Terrestrial Plants • Problem Species • Terrestrial Pests and Pathogens • Succession • Soils	Monitor terrestrial vegetation to document changes due to a variety of natural and anthropogenic stressors including, pests, pathogens, exotic species, and browse by ungulates.	o Are plant communities changing? o Is plant community structure changing? o Which key terrestrial pests and pathogens are present in Great Lakes national parks and at what abundance? o To what degree is deer browse evident on terrestrial vegetation? o Are Great Lakes Network forests exhibiting natural successional trajectories? o Are the depths of soil horizons changing at sites, between sampling events?
Landbirds	• Bird Communities	Monitor landbirds each spring as an index to their abundance in parks of the Great Lakes Network, using methods that are comparable to other landbird monitoring across the region and the nation.	o What is the composition and relative abundance of landbirds along selected transects in the parks during the breeding season? o What are the habitat associations of landbird species? o What are the long-term trends in indices of landbird populations? o How do population indices and habitat associations in the parks compare to other monitoring programs in the region?

Table 5.2. Protocol objectives and monitoring questions, continued.

Protocol	Vital Sign(s)	Objective	Monitoring Questions
Bioaccumulative Contaminants	• Trophic Bioaccumulation	Provide managers with knowledge on the trends and ecological effects of targeted, human-made toxic chemicals that are known to bioaccumulate in aquatic ecosystems of park units in the Great Lakes Network.	o What is the magnitude and direction of change in concentrations of select contaminants that bioaccumulate in tissues of indicator species? o Is the reproductive success of target species changing and is it associated with contaminants? o Are deformities evident in individuals from target populations and are they associated with contaminants?
Amphibians	• Amphibians and Reptiles	Provide information on occupancy, distribution, and relative abundance for a suite of amphibians that are integrators of environmental stressors in aquatic and terrestrial systems	o Are there within or among-park trends in occupancy of targeted species? o Are occupancy trends associated with environmental variables or other GLKN Vital Signs? In particular, are species' distributions changing northward or closer to large water bodies in concert with longer-term climatic changes? o How does the magnitude and direction of change in species occupancy compare regionally or nationally? o How does detectability vary among observers, park units, years, and species? o What is the relative abundance of targeted species at each site?

Chapter 6 – Data Management

INTRODUCTION

Collecting data on specific natural resource variables is our first step toward understanding the ecosystems within our national parks. These ecosystems are changing, as is our knowledge of them and how they work. We use monitoring data to analyze, synthesize, and model aspects of ecosystems. In turn, we use our results and interpretations to make decisions about the parks' vital natural resources. Thus, *data* collected by researchers and maintained through sound data management practices will become *information* through analyses, syntheses, and modeling. Information is the common currency among the many different activities and people involved in the stewardship of NPS natural resources. Users of network generated information include park managers, cooperators, researchers, and the general public.

Data management refers to the attitudes, habits, procedures, standards, and infrastructure related to the acquisition, maintenance, and disposition of data and its resulting information. Data management is not an end unto itself, but instead is the means of maximizing the quality and utility of our natural resource information. This is particularly important for long-term programs, in which the lifespan of a data set will likely be longer than the careers of the scientists who developed it. Seen in this way, it becomes obvious that data management is vital to the success of any long-term monitoring initiative.

This chapter summarizes the system of data management that will be used by the Great Lakes Network. This system is explained more completely in the Network's Data Management Plan (DMP). See Appendix A, Supplemental Document 8 (Hart and Gafvert 2005). The complete DMP presents the overarching strategy for ensuring that program data are documented, secure, accessible, and useful for decades into the future. The plan also refers to other guidance documents, SOPs, and detailed protocols that convey specific standards and steps for achieving our data management goals. The Data Management Plan is the foundation that we will build upon as new protocols are developed, advances in technology are adopted, and new concepts in data management philosophy are accepted.

DATA MANAGEMENT GOALS AND OBJECTIVES

The goal of our data management system is to ensure the quality, interpretability, security, longevity, and availability of ecological data and related information resulting from resource inventory and monitoring efforts.

- ***Quality.*** The Network will ensure that appropriate quality assurance measures are taken during all phases of project development, data acquisition, data handling, summary and analysis, reporting, and archiving. Because standards and procedures can only accomplish so much, an important part of quality assurance is to continually encourage careful attitudes and good habits among all staff involved in creating, collecting, handling, and interpreting data.
- ***Interpretability.*** A data set is only useful if it can be readily understood and appropriately interpreted in the context of its original scope and intent. Data taken

out of context can lead to misinterpretation, misunderstanding, and bad management decisions. Sufficient documentation (e.g., metadata) will accompany each data set, and any reports and summaries derived from it, to ensure that users will have an informed appreciation of the context, applicability, and limitations of the data.

- ***Security.*** The Network will ensure that both digital and analog forms of source data are maintained and archived in an environment that provides appropriate levels of access to project managers, technicians, decision makers, and other users. Our data management system will take advantage of existing systems for Network security and systems backup, and augment these with specific measures aimed at ensuring the long-term security and integrity of our data.
- ***Longevity.*** Countless data sets have become unusable over time either because the format is outdated (e.g., punchcards) or because metadata is insufficient to determine the collection methods, scope and intent, quality assurance procedures, or format of the data. Proper storage conditions, backups, and migration of data sets to current platforms and software standards are basic components of data longevity. Comprehensive data documentation is an essential component of data management. The GLKN will use a suite of metadata tools to ensure that data sets are consistently documented, and in formats that conform to current federal standards.
- ***Availability.*** Natural resource information can only inform decisions if it is available to managers at the right time and in a usable form. Our objective is to expand the availability of natural resource information by ensuring that the products of inventory and monitoring efforts are created, documented and maintained in a manner that is transparent to the potential users of these products. The Network will endeavor to provide natural resource managers easy, secure, and continuous access to its data and analyses, based on the users' needs.

DATA MANAGEMENT ROLES AND RESPONSIBILITIES

For the GLKN monitoring program to work effectively, all employees will have data stewardship responsibilities. The GLKN Data Management Plan specifies the roles and responsibilities of individuals involved in the production, analysis, management, and reporting of data and information. This includes field workers, natural resource specialists, program ecologists, GIS specialists, and other specialists such as biometricians. More detailed roles and responsibilities are given in the protocol for each Vital Sign. Table 6.1 lists the basic roles and responsibilities of individuals involved in monitoring projects, although not all of them will be involved in every project and individuals may assume multiple roles. For example, a network ecologist may have a role in developing a project protocol and ongoing involvement in issues related to ecological science, and at the same time may serve as the project manager for the same project.

Chief personnel involved with data management include the project manager and the data manager. Figure 6.1 illustrates the core data management duties of the project manager and data manager and where they overlap.

Table 6.1. Roles and responsibilities for data stewardship.

Role	Data Stewardship Responsibilities
Project Manager	Oversee and direct project operations, including data management
Project Crew Leader	Supervise crew members and organize data
Project Crew Member	Collect, record, and verify data
Network Ecologist	Integrate science with Network data and activities
Network Coordinator	Coordinate and supervise all Network activities
Network Data Manager	Ensure inventory and monitoring data are organized, useful, compliant, safe, and available
Database Specialist	Know and use database software and database applications
Network GIS Manager	Support Network objectives with GIS and resource information
GIS/Data Specialist	Process and manage data
Information Technologist	Provide IT support for hardware, software, and networking
Statistician or Biometrician	Analyze data and/or consult on analysis
Park Research Coordinator	Facilitate research and data acquisition in a park. Communicate NPS and park requirements to permit holders
Curator	Oversee all aspects of specimen acquisition, documentation, preservation, and use of park collections
I&M National Data Manager	Provide Servicewide database availability and support
End Users (managers, scientists, interpreters, and public	Inform the scope and direction of science information needs and activities. Apply data and information services and products.

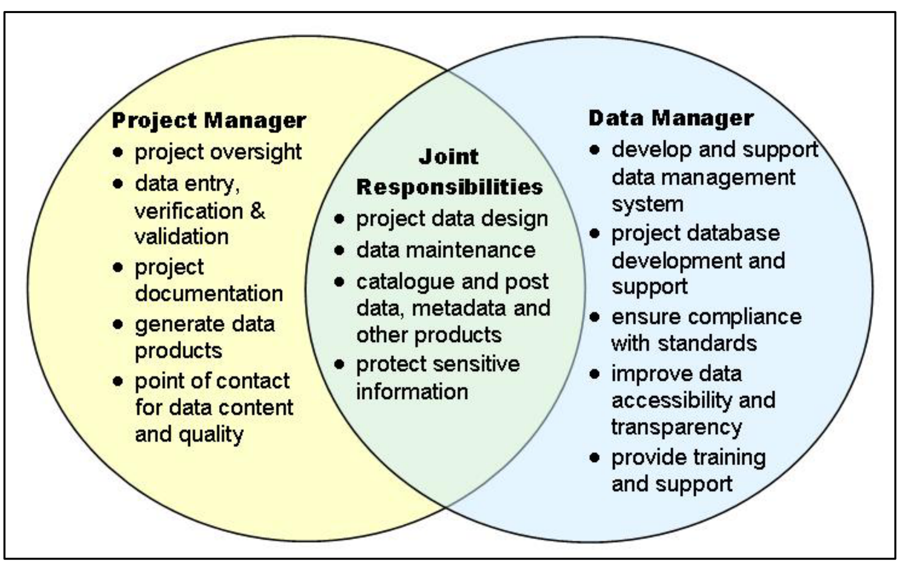


Figure 6.1. Core data stewardship duties of project managers and data managers.

PROJECT WORK FLOW AND THE DATA MANAGEMENT PROCESS

Both short-term and long-term projects share many work flow and data management characteristics. Most GLKN projects consist of five primary stages: planning and approval; design and testing; implementation; product integration; and dissemination of information, evaluation, and closure. Each stage is characterized by a particular set of activities.

- ***Planning and Approval.*** Establishing the project scope and objectives is the most important step in project development. It is crucial that Network and park staff work together at this stage to establish what data are needed, why they are needed, how they will be used, and any unique data management requirements.
- ***Design and Testing.*** At this stage, specifications are established for how data will be acquired, processed, analyzed, reported, and made available to others. The project manager and data manager work together to develop specific procedures (SOPs) related to data acquisition, processing, analysis, and quality control. Also, the project manager and data manager collaborate to develop the data design and data dictionary, in which the specific variables that will be collected are described in detail. In addition, decisions should be made regarding integration and permanent storage of deliverables as they are produced.
- ***Implementation***. During the implementation phase, data are acquired, processed, error-checked and documented. Although data collection and processing methods will vary among projects, each project will require data verification and validation. All aspects of data acquisition should be specified in project protocols and SOPs. Similarly, metadata should include documentation of quality assurance measures. During this phase, the data are preliminary and available only to individuals involved in the project.
- ***Product Integration and Data Dissemination.*** During this stage, data products and other deliverables are integrated into national and Network databases, metadata records are finalized and posted to clearinghouses, and products are distributed or made available to the project's intended audience(s). This is also when items that belong in collections or archives are accessioned and cataloged. Certain projects, such as those conducted jointly with other agencies and using a common database, may have additional integration needs.
- ***Evaluation and Closure.*** For long-term monitoring and other cyclic projects, this phase occurs at the end of each field season and leads to an annual review of the project. After products are cataloged and made available, program administrators, project managers, and data managers will assess how well the project met its objectives, determine what might be done to improve various aspects of the project methodology, and evaluate the usefulness of the resulting information.

Following evaluation, changes will be incorporated into the protocol as needed. This may necessitate redesign and testing or simply a procedural change in the implementation phase. The evaluation process involves feedbacks and reassessments, in essence becoming an iterative process.

STRATEGIES FOR DATABASE DESIGN

Long-term monitoring projects conducted by the Network will have modular, stand-alone project databases that share design standards and centralized validation tables. The project databases will be developed in a desktop database application or a GIS geodatabase application, depending on the requirements of a project and the desires of the project manager. Because all natural resource monitoring consists of observations and measurements taken at specific geographic locations, nearly all the Network's monitoring data sets are inherently suited to management in a geographic information system (GIS). The Network's data management vision involves maintaining a close spatial link to associated monitoring data in a format that allows it to be readily visualized in a geographic context. A generic name for a spatially explicit data structure is a geodatabase. There are numerous advantages to maintaining project-specific (geo)databases:

- Data sets are modular, allowing greater flexibility in accommodating the needs of each project area. By having project-specific data sets, databases and protocols can be developed at different rates without a significant cost to data integration. In addition, one project database can be modified without affecting the functionality of other project databases.
- By working up from modular data sets, we avoid a large initial investment in a centralized database and the concomitant difficulties of integrating among project areas with very different – and often unforeseen – structural requirements. Furthermore, the initial investment in integration may not result in greater efficiency in the future.

Standards for project databases ensure compatibility among data sets, and are essential given the often unpredictable ways in which data sets are aggregated and summarized. When well conceived, standards encourage sound database design and facilitate interpretability of data sets. Shared 'lookup' tables (e.g., species lists, park names, common location information) help standardize data and facilitate integration. As much as possible, GLKN standards for fields, tables, and other database objects will mirror those conveyed through the Natural Resource Database Template. Where differences between local and national standards exist, the rationale for these differences will be documented. In addition, documentation and database tools (e.g., queries that rename or reformat data) will be developed to ensure that data exports for integration are in a format compatible with current national standards.

Although stand-alone databases work well at the project level, they are not efficient for analysis across ecological indicators and at the ecosystem or park management level. In addition, the Network must make its data sets readily available to appropriate user groups. Because GIS software vendors have focused on making data transfer between desktop geodatabases and enterprise geodatabases very efficient, the opportunity to combine the project databases into a SQL (Structured Query Language) database that contains all the common and unique tables of each project offers promise for reducing the Network's data management tasks and giving the Network's data users a single access point. The Network is developing a web portal as its primary mechanism for distributing data. The site is based on an enterprise SQL relational database and includes an Internet Mapping Service (IMS).

DATA AND INFORMATION INFRASTRUCTURE

The GLKN program relies in part on park, regional, and national IT personnel and resources to maintain the computer resource infrastructure. This includes, but is not limited to, hardware replacement, software installation and support, security updates, virus-protection, telecommunications networking, and backups of servers. Therefore, communication with park and regional IT specialists is essential to ensure service continuity for our system architecture.

An important element of a data management program is a reliable, secure network of computers and servers. Our digital infrastructure has three main components: a network-based local area network (LAN), network data servers, and servers maintained at the national level (Figure 6.2). This infrastructure is maintained by Network and national IT specialists, who administer all aspects of system security and backups.

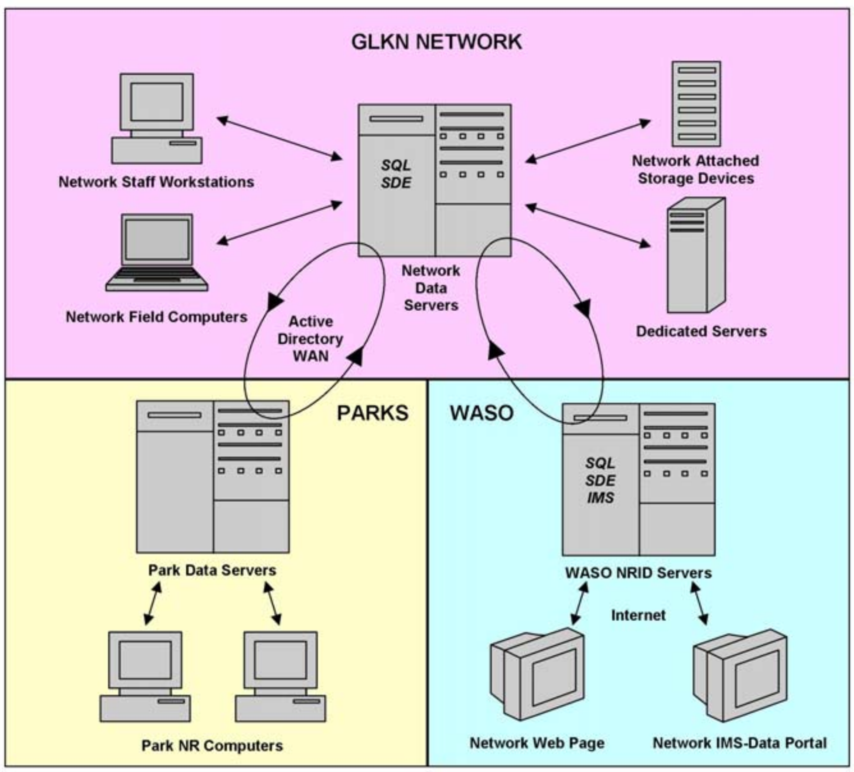


Figure 6.2. Schematic representing the logical layout and connectivity of computer resources within the GLKN core user groups. Each of these components hosts different parts of our natural resource information system.

National-level Infrastructure

Data management support from the Washington office includes hosting and maintaining several databases for summarizing park natural resource data at the national level. These online applications include:

- *NatureBib* – the master database for natural resource bibliographic references

- *Biodiversity Data Store* - a digital repository of documents, GIS maps, and data sets that contribute to the knowledge of biodiversity in National Park units, including presence/absence, distribution, and abundance
- *NPSpecies* – a biodiversity database application that lists the species that occur in or near each park, and the physical or written evidence for the occurrence of the species (i.e., references, vouchers, and/or observations)
- *NR-GIS Data Store* – a centralized repository and graphical search interface that links data set metadata to a searchable data server on which data sets are organized by NPS units, offices and programs

Region-level Infrastructure

The Midwest Region contributes to the inventory and monitoring infrastructure through higher-level networking and communications support, and the participation of the regional GIS coordinator and associated staff. The Network has GIS expertise in Network staff positions; however, several Network parks lack GIS personnel. The Regional GIS Support Office has been cooperating with GLKN to assist member parks with training, GIS project needs, and remote sensing projects. In addition, the regional GIS staff provides the Network with the first level of technical support for some GIS software applications.

Network-level Infrastructure

The Network has implemented a central server system to provide access to shared information resources. The strategy is to maintain a relational database management system (RDBMS) that allows for central management of common tables and high-value, long-term project databases and provides a means of maximizing performance in a distributed, multi-user environment. This is part of the Network's enterprise GIS/SQL strategy. The following types of materials are maintained on these Network data servers:

- Enterprise SQL Database – this will be used primarily to feed the Network's web portal, which will be used both internally and externally, but it will also provide a single source for the compiled data sets for monitoring projects and other multi-year efforts that have been certified for data quality
- Common lookup tables and data sets – for example, parks, projects, personnel, species, base GIS resources
- Project tracking application – used to track the status, deliverables, due dates, and responsibilities for each monitoring protocol
- Network digital library – Network repository for finished versions of project deliverables for Network projects (e.g., reports, methods documentation, data files, metadata, etc.)

Data redundancy, use of data servers, and distribution of final products are highlights of GLKN's information management infrastructure. Redundancy means that data are fully backed up and stored at an off-site location. This is crucial for information recovery in case of a local catastrophe at one of the host sites. Backups will be automated through scheduled services. Data servers will act as a repository for data and data products generated by the program. These data will be accessible to authorized personnel via an IMS web portal being developed by Michigan State University and Colorado State University. Security permissions will be granted down to the project level and access to preliminary or sensitive data will be carefully controlled. Finalized data products and related information will be uploaded to online national databases (NatureBib, NPSpecies, NR-GIS Metadata Database, and NR-GIS Data Store) for public access.

Given our collaboration with other agencies and organizations, certain GLKN data sets may be maintained by outside organizations. In such cases, we will maintain local copies of metadata for these data sets. In cases where access to the information systems supported by cooperators do not meet the Network's needs, versioned copies of data sets may be maintained on our servers to ensure data availability.

Park-level Infrastructure

Because GLKN work is largely conducted in the member parks, for the primary purposes of informing resource managers, the Network has a high degree of data exchange with its parks. Information resources shared between the Network and parks include:

- Local applications – desktop versions of database applications for a specific Network or park need
- Working files – draft geospatial themes, drafts of reports, administrative records
- Park digital library – base spatial data, imagery, and finished versions of park project deliverables
- Park GIS files – base spatial data, imagery, and project-specific themes

DATA LIFE CYCLE

The types of data handled by the Network fall into three general classifications:

- Program data are produced by projects that are either initiated (funded) by the I&M Program or involve the I&M Program in another manner (e.g., natural resource inventories and Vital Signs monitoring projects).
- Non-program legacy/existing data are produced by NPS entities without the involvement of the I&M Program (e.g., park inventory projects).
- Non-program external data are produced by agencies or institutions other than the National Park Service (e.g., weather and some water quality data).

The life cycle of data sets from each of these sources could vary considerably. For instance, partner climatic data may be acquired with considerable quality assurance and quality control review and with complete data documentation, negating the need for the Network to duplicate these tasks.

Data Acquisition and Processing

Past investments in natural resource data collection in the GLKN parks have resulted in a legacy of products that vary widely in format, consistency, and value for park stewardship. The Network has invested substantially in identifying and documenting these legacy data sets, and in cases where they were of potential future benefit to monitoring, efforts have been made to bring data sets into compliance with current Network and NPS data standards. To help address the volume of natural resource data stored at the parks, the Network currently supports activities to obtain, catalog, report, and archive data in NPSpecies, NatureBib, and in metadata catalogs. Future work and expense to link legacy data with management requirements will be carefully scrutinized by the Network and park natural resources staffs to evaluate its potential value to current and future projects and management. Although initial GLKN-funded inventories have been completed, the Network and its member parks will continue to perform inventories according to the spirit and goals of the Natural Resource Challenge when funding is available.

In order to provide a synthesis of scientific information based on Vital Signs and related data, the Network also gathers and processes relevant data and information from other park-based and external inventory and monitoring efforts. In some cases, access to these external data sources may require the Network to enter into agreements or memoranda of understanding, or purchase subscriptions.

Most data acquired by the Network will be collected as field data (inventories and monitoring studies). Tools and methods for field data collection, such as paper data forms, field computers, automated data loggers, and GPS units will be specified in individual monitoring protocols and study plans. Various factors will determine what methods and tools are used in the field, including: data quality, security, efficiency, and a project manager's comfort level with the method employed. Field crew members will closely follow the established SOPs in the project protocol.

Quality Assurance

Long-term monitoring is only useful if users have confidence in the data. Efforts to detect trends and patterns in ecosystem processes require high-quality, well-documented data that minimize error and bias. Data of inconsistent or poor quality can result in loss of sensitivity and lead to incorrect interpretations and conclusions.

NPS Director's Order #11B: Ensuring Quality of Information Disseminated by the National Park Service (www.nps.gov/policy/DOrders/11B-final.htm) specifies that information produced by the NPS must be of the highest quality and be based on reliable data sources that are accurate, timely, and representative of the most current information available. Therefore, GLKN will establish and document procedures for quality assurance (QA) and quality control (QC) to identify and reduce the frequency and significance of errors at all stages in the data life cycle. Under these procedures, the progression from raw data to verified data to validated data implies increasing confidence in the quality of those data. Quality assurance and quality control procedures will document internal and external review processes and include guidance for handling problems with data quality.

Although the specific QA/QC procedures employed will depend on the Vital Signs being monitored, some general concepts apply to all Network projects. Examples of QA/QC practices include:

- Standardized field data collection forms
- Use of field computers and automated data loggers

- Proper calibration and maintenance of equipment
- Field crew and data technician training
- Database features such as built-in pick lists and range limits to reduce data entry errors
- Automated error-checking routines

We appraise data quality by applying verification and validation procedures. Data verification checks that the digitized data match the source data, and data validation checks that the data make sense. The Data Management Plan describes several methods for verifying and validating data, and each monitoring protocol will include specific procedures for assuring data quality.

A final report on data quality will be incorporated into the documentation for each project. Such documentation will include a listing of the specific methods used to assess data quality and an assessment of overall data quality prepared by the project manager.

Data Documentation

Data documentation is a critical step toward ensuring that all data sets retain their integrity and utility well into the future. Data documentation refers to the development of metadata. At the most basic level, metadata is 'data about data'. More specifically, it is information about the content, context, structure, quality, and other characteristics of a data set. Without meaningful metadata, potential users of a data set have little or no information regarding the quality, completeness, or manipulations performed on a particular 'copy' of a data set. Additionally, standardized metadata provide a means to catalog data sets within intranet and internet systems, thus making them available to a broad range of potential users.

At a minimum, GLKN will require the following elements for documentation of all data managed by the Network:

- Formal metadata compliant with Federal Geographic Data Committee (FGDC) standards, the National Biological Information Infrastructure (NBII) Profile (where appropriate), and the NPS Metadata Profile for all geospatial and biological data sets
- Project documentation, including data dictionaries.

The Network will create all metadata according to NPS standards and guidelines. Formal metadata will be created using ArcCatalog in conjunction with NPS Metadata Tools and Editor. The Network will publish all of its metadata to the online NR-GIS Metadata Data Store. All documentation will also be maintained with its accompanying data set(s) on the Network's data server and its web portal for data visualization and dissemination.

Data Dissemination

One of the most important goals of the I&M Program is to integrate natural resource inventory and monitoring information into NPS planning, management, and decision making. To that end, the Network will use a variety of data and information systems and employ tools that allow potential users to browse, query, and obtain data, information, and supporting documents easily. The primary system that the Network will use for data access is its IMS web portal. In addition to on-screen visualization, the IMS website allows data sets and their metadata to be downloaded based on custom queries in industry standard file formats (e.g., MS Excel and delimited text file structures). Other data access systems include the GLKN's data server and digital library, the Network's website, and national applications with internet interfaces (NatureBib, NPSpecies, NR-GIS Data Store, etc.)

Network products will be available on request and will be distributed using file transfer protocol (FTP), attaching reports and other products with small file sizes to email, and shipping digital media such as DVDs, CD-ROMs and other disposable data storage products.

Data Maintenance, Storage, and Archiving

The Network will implement procedures to protect information over time. These procedures will ensure that digital and analog data and information are:

- up-to-date in content and format so they remain easily accessible and usable, and
- protected from catastrophic events (e.g., fire and flood), user error, hardware failure, software failure or corruption, security breaches, and vandalism.

Technological obsolescence is a significant cause of information loss, and data can quickly become inaccessible to users if they are stored in out-of-date software programs, on outmoded media, or on deteriorating (aging) media. Effective maintenance of digital files depends on the proper management of a continuously changing infrastructure of hardware, software, file formats, and storage media. As software and hardware evolve, data sets must be consistently migrated to new platforms or saved in formats that are independent of specific software or platforms (e.g., ASCII delimited text files). Storage media should be refreshed (i.e., copied to new media) on a regular basis, depending upon the life expectancy of the media.

Regular backups of data and off-site storage of backups are the most important safeguards against data loss; therefore, the Network has established data maintenance and backup schedules for data stored on the Network data servers. Although each staff member is required to backup data on personal workstations, active computers connected to the Network LAN are included in a scheduled backup one night each week.

WATER QUALITY DATA

Water quality data, including macroinvertebrate characteristics, are managed according to guidelines from the NPS Water Resources Division (Figure 6.3). These guidelines include using the NPSTORET desktop database application at the parks to help manage data entry, documentation, and transfer. The Network oversees the use of NPSTORET according to the Network's water quality monitoring protocols and ensures the content is transferred at least annually to NPS Water Resource Division for upload to the EPA STORET (STOrage and RETrieval) database.

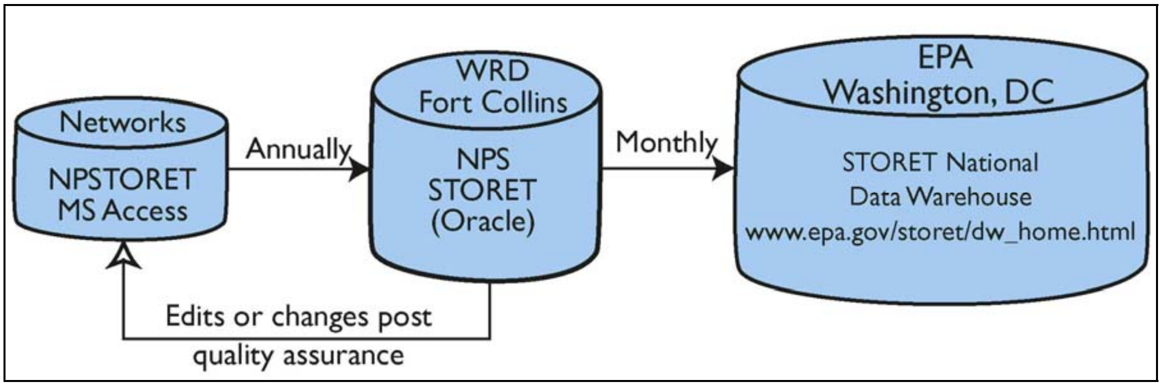


Figure 6.3. Water Quality Flow Diagram.

DATA OWNERSHIP AND SENSITIVITY

Network data and information products are property of the NPS. However, the Freedom of Information Act (FOIA) establishes the right for any person to access federal agency records that are not protected from disclosure by any exemption or by special law enforcement record exclusions. The GLKN complies with all FOIA strictures regarding sensitive data. A number of laws and regulations (see NPS Director's Order #66) allow for restricted access to information the may imperil a resource if released. Through these regulations, information that could result in harm to natural resources can be classified as 'protected' or 'sensitive' and withheld from public release (National Parks Omnibus Management Act (NPOMA).

Project managers, in conjunction with the appropriate park staff, determine data sensitivity in light of federal law and stipulate conditions for release of the data in the project protocol and metadata. The investigators, whether Network staff or partners, will develop procedures to flag information related to sensitive resources in all products, including documents, maps, databases, and metadata.

Chapter 7 – Analysis and Reporting

ANALYSIS

Overview

The Great Lakes Network will strive to provide reliable information on the status and trend of natural resource indicators in a manner that informs park managers and allows them to assess whether park goals and mandates are being achieved. As we outline later in this chapter, there are many expected audiences for Network information, each with perhaps a different interest in the results and different familiarity with the systems described. Analytical approaches for each indicator (Vital Sign) are described in greater detail in each protocol, but are summarized here as an overview. We also outline some principles for our analytical approaches, and describe the strategy and outlets for communicating progress and results. In contrast to many other spatially extensive monitoring programs, we seek an integrated monitoring vision that encompasses several disparate but linked ecosystem components; correspondingly, analyses and reporting will promote this vision. The extent and depth of analysis in future years depends upon continued programmatic and competitive source funding.

Relationship of analyses to other steps in the monitoring process

Well-developed monitoring strategies have clear connections between questions of interest, appropriate sampling designs, and resulting analytical approaches (Noon 2003). Accordingly, the utility and robustness of our analyses are predicated upon the formulation of biologically meaningful questions and relationships, as expressed in our conceptual models (Gucciardo et al. 2004). While different analytical options exist, well-refined questions will prescribe certain analytical approaches, thereby removing any guesswork.

Increasingly, ecologists seek to elucidate and quantify biologically important phenomena, rather than doggedly pursue statistical significance (Johnson 2002, Anderson et al. 2001, Johnson 1999, Yoccoz 1991). The Great Lakes Network seeks first and foremost to provide a quantitative understanding of the magnitude and direction of change and to provide appropriate measures of precision of the estimate. We are striving to address directed monitoring questions that reflect our prior knowledge of the system and provide useful information for management decisions, rather than test myriad hypotheses about ecosystem change.

In addition to quantifying the status and trends of Vital Signs, a secondary goal is to begin to understand the dynamics and drivers (some of which are Vital Signs themselves, such as weather and land use) of our indicators, following our conceptual models. Although not every trend is a product of local management action or inaction, tests of association that begin to address the underlying 'why' questions behind the 'what' questions in trend analysis will be explored for at least a subset of Vital Signs. We have generally adopted sampling designs that optimize quantification of indicator values across the spatial domain of interest, rather than of the effect of a particular factor on indicator values. Nonetheless, in some cases, we have purposefully allocated samples across a gradient of a stressor (e.g., vegetation sampling at APIS islands at varying distances from the mainland and with a range of deer density). Such approaches increase the likelihood that our monitoring can lead to correction of trend before the genetic, demographic, and stochastic problems that impinge upon small populations (Caughley 1994) become irreversible.

Finally, in both our analysis and reporting strategies, we are seeking to consistently link monitoring to the decision-making process (Noon 2003, Noon et al. 1999). Thus, in some sampling cycles we may reserve a portion of monitoring effort to address one or two specific, management driven questions in a limited but statistically powerful manner. Such targeted effort would be occasional, have a short duration, and would not replace our routine monitoring. Questions that could be addressed include, for example, assessing whether the cover of ruderal and non-native plant species is higher along newly created road corridors than in other areas of the park, and whether areas with trail closures in certain seasons exhibit higher species richness of amphibians than areas with year-round use.

We expect that results of our monitoring programs will be viewed and interpreted in the context of other Vital Signs, programs of other agencies, and research efforts.

Types of studies to describe and learn about the natural world

Ecologists commonly use three types of studies to describe the natural world – observational studies, manipulative experiments, and natural experiments. Our monitoring will primarily consist of observational study, but we will conduct natural experiments if disturbance occurs in a spatial manner that allows investigation with little or slight modification of our existing designs.

In observational studies (also termed "mensurative experiments"; Hurlbert 1984), treatments (e.g., disease, fire, visitor activities) are not assigned randomly across the population of sampled units (Cochran 1983). Consequently, such studies do not allow for the unequivocal testing of cause-effect relationships, because other (unmeasured) variables may be the cause of any differences observed, rather than the putative treatment. In spite of their drawbacks, observational studies are attractive in the sense that they often have higher external validity (i.e., ability to extrapolate findings) to the system(s) of interest, especially when they have high sampling replication. Because observational studies cannot control environmental and other factors, it is not possible to obtain a replicate independent data set under the same conditions. However, corroboration of an observed phenomenon by other indicators, across different domains, or by different investigators strengthens acceptance of any given result. These last two types of corroboration have been termed "metareplication" and provide some of the strongest indication that an observational result is biologically important rather than an artifact of method, investigators, temporal or spatial domain, or other factors (Johnson 2002).

On the other end of the spectrum are manipulative experiments, in which treatments are assigned randomly to a population of subjects, often under very controlled conditions. Manipulative experiments provide the strongest inference about how changes in the manipulated factor directly (or indirectly) effect changes in the response variable. Because experiments often occur in controlled laboratory conditions or within very spatially restricted areas in the field, they tend to have questionable external validity to field conditions. Another drawback for NPS-administered lands, particularly those with wilderness, is that manipulative experiments may conflict with the philosophy (e.g., 'naturalness'; Landres 2005) and legislation of NPS management.

Intermediate between these two types are 'quasi-experiments' or natural experiments (Zar 1999, Sokal and Rohlf 1995) in which investigators take advantage of events such as disturbances to investigate the effect of a particular event on one or more response variables. In a sense, these types of investigations merge the positive aspects of both observation and experiment, in that they occur in the areas about which investigators wish to make inference and can be spatially extensive yet treatment has been provided by natural (e.g., catastrophic) process rather than by investigators. The Great Lakes Network will stay alert for these instances, because: a) they allow tests of the effects of both natural and anthropogenic disturbances; and b) their strength of evidence is bolstered by pre-event data, which we expect our sampling design will provide in most situations. This last property makes such monitoring similar to the before-after-control-impact (BACI) designs of environmental impact studies (Benedetti-Cecchi 2001, Schmitt and Osenberg 1996).

Steps in data analysis

Data analysis consists of four steps, including summarization and characterization of data, determination of status, evaluation of trends, and synthesis (Table 7.1). Data summarization and characterization help ensure integrity of the data, and provide the foundation for more comprehensive analyses and for effective communication of results (Reid 2001, Palmer and Mulder 1999). Status refers to the condition of the monitored variables at a single point in time, and should be quantitatively understood across the entire spatial domain of interest. Evaluation of trend requires at least three successive measurements of the indicator, and seeks to quantify change over time. Investigation of interannual (rather than seasonal or diel) trends encompasses the primary goal of the I&M monitoring program, though existence of strong seasonality and diurnal rhythms in ecosystems of the Great Lakes region affect our sampling strategy. Repeated measures will be a common analytical framework for measurements that are replicated across space or have shorter duration of monitoring. In contrast, time-series analysis is applicable for a single unit measured at least 30 times (e.g., 30 yrs), most common with individual climate and air-quality stations. Finally, synthesis involves the interpretation of monitoring results, placing of results within the body of existing knowledge, and discussing potential management implications. We will be using a number of statistical analysis packages including JMP™, SAS®, R, STATISTIX®, and PC-ORD.

Types of analytical approaches

Both across constituencies (natural-resource staff from individual parks, Network staff, and outside scientists) and across indicators, a diverse list of questions has been proposed for focusing monitoring efforts. These questions span a range of temporal and spatial scales, levels of biological organization, types of ecosystem indicators (i.e., structure, composition, and function), and trophic levels (Table 5.2, Table 7.1). Consequently, analytical approaches to such diverse questions are not easily summarized.

Table 7.1. Techniques and persons responsible for analysis of Vital Signs monitored by the Great Lakes Inventory and Monitoring Network. See Table 7.2 for report type (* in column 1); in the central column the analyses or methods used are listed in brackets.

Level of Analysis * report type	**Description and Techniques**	**Lead Analysts**
Data Summarization/ Characterization *Annual Summary Reports	Calculation of basic statistics of interest and initial screening, including: • Measures of central tendency [mean, median, or geometric mean] • Measures of confidence [standard error, confidence intervals], distribution [skew], and variability [standard deviation, variance] • Identification of missing values and outliers [box-and-whisker plots, queries, QA/QC] • Visual inspection of data [tables, appendices] Summarization encompasses both measured and derived variables mentioned in the monitoring protocols, as well as creation of data matrices for community analyses.	Field staff perform QA/QC, and begin characterizing data. Project managers produce summaries, with guidance from the quantitative ecologist. Collaborators and partners may also contribute.
Status Determination *Analysis and Synthesis Reports *Scientific journal articles *Briefings *Conference presentations	Analysis and interpretation of the status of a Vital Sign that seeks to answer: • Do observed values exceed a regulatory standard, or a known or hypothesized ecological threshold? • How do observed values compare with the range of historical variability (when it is known or estimated) for a Vital Sign? • What is the level of confidence (e.g., standard error) in the status estimate? • What is the spatial distribution (within the park, Network, or ecoregion) of observed values at time t_x? • Do these patterns suggest strong relationships with other factors not accounted for in the design? Distributional assumptions about the target population(s) and the level of confidence in the estimates will be assessed during analyses.	Project managers, with guidance from the quantitative ecologist. Participation from collaborators, partners, and subject-matter experts will also be sought. Insights from data collectors may be used to prescribe some tests.
Trends Evaluation *Analysis and Synthesis Reports *Scientific journal articles *Briefings *Conference presentations	Evaluations of interannual trends will seek to address: • Is there continued directional change in values of an indicator over the period of measurement? • What is the estimated rate of change (and the associated measure of uncertainty) for the indicator? • How does this rate compare with rates observed from historical data, other indicators from the same area, or with other comparable monitoring in the region? •Is there significant departure from the originally estimated (or simulated) power to detect trend? If so, why? • Are there unforeseen correlations that suggest other factors should be incorporated as covariates? [correlations, regression analyses] Analysis of trends will initially employ simple graphic portrayals, then repeated-measures, time-series, and other analyses, often with mixed linear models.	Project managers, the Network's quantitative ecologist, and protocol developers. Input will also be sought from cooperators, partners, other park and Network staff, and outside investigators.
Synthesis *Analysis and Synthesis Reports *Scientific journal articles *Briefings *Conference presentations	Examination of patterns across Vital Signs; associations between indicators, stressors, and drivers; and tests of specific management-oriented questions, which will include: • Tests of hypothesized relationships, congruence among indicators, and the importance of covariates • Confirmatory and occasional exploratory analyses in model selection (Burnham and Anderson 2002) • Integrative approaches [ordination of community data, multiple regression, diversity and conservation-value indices, (rarely) path analysis and structural equation modeling] • Evaluation of competing *a priori*-specified models that explain dynamics in indicator; model averaging, variable weights, and forecasting [information-theoretic analyses] Synthetic analyses require close interaction with academic and agency researchers, and may employ myriad approaches as new indicators and questions are included. Integration with existing results from other monitoring and research is critical.	Project managers and the quantitative ecologist will normally perform most synthetic analysis, though input and review will be pursued widely.

Given that financial resources and personnel are limited, we have sought to restrict our attention to a small subset of tractable questions for indicators that: a) can be precisely, repeatably, and relatively inexpensively sampled; b) show a rapid, persistent response to environmental changes; c) have dynamics that reflect the ecosystem or environmental component of interest; and d) have relatively low natural variability, allowing separation of background variation from a change in status (Noon et al. 1999). In addition to estimating magnitude of change and associated confidence intervals, we will use a combination of the four analytical approaches detailed below. Because analyses for each Vital Sign will involve many different analytical approaches, Table 7.1 is not exhaustive. More details on each analysis will be provided in individual protocols.

Hypothesis testing

This category of analysis will largely be reserved for testing whether status of a particular indicator meets a certain condition. This may be used to satisfy a particular congressional mandate or achieve a particular management or performance goal. Previously, nearly all monitoring questions were framed in terms of a statistical null hypothesis of no difference between the estimated value (status) of an indicator and its hypothesized baseline or reference value (Noon et al. 1999, Underwood 1997). However, estimating reference values ('benchmarks') is difficult and imprecise for several reasons (reviewed by Noon et al. 1999), including the recognition that benchmarks for indicators may be better represented by probability distributions rather than a single target value. One alternative to traditional null-hypothesis testing is bio-inequivalence testing, in which the rejection region is split into two sides and the test postulates that the difference between two samples is greater than the 'equivalence interval' (McBride 2005).

Model selection and information-theoretic approaches

Although the concept of multiple working hypotheses (as compared to a single statistical null vs. an alternative; Chamberlin 1890) has long existed, it did not gain broad support in ecological studies until recently. Analytical procedures (Akaike 1974) to handle such a framework are called information-theoretic because they derive from Kullback-Leibler 'information' theory (Kullback and Leibler 1951). In the approach, one seeks to compare the strength of evidence in support of various approximating models (hypotheses) that contain varying numbers of factors, to select the model that loses as little information as possible about truth. Information-theoretic approaches focus on the *relative* strength of the competing models, rather than on the importance of any single variable or model. Nonetheless, importance of individual variables can be obtained via calculation of variable weights, and either r^2 values or the relative weight or rank of the null model indicate how good a given model is at describing variability in the response variable (Eberhardt 2003, Burnham and Anderson 2002).

The competing models are ranked on two criteria – fit of the data to the model, and penalty for having too many variables. Information-theoretic analyses, which are generally discussed in a strength-of-evidence framework, have two properties that match humans' attempts at incremental understanding of natural systems. First, they allow for the potential existence of more than one plausible model, and provide a ratio of how much more likely the best-supported model is than each of the remaining models. Secondly, rather than making inferences on only the best model, it is possible to base inference on the weighted average of all the models (multi-model inference). For example, in our initial monitoring efforts for amphibians, we will use model selection to determine which biotic and abiotic factors most strongly influence species detectability. We envision that such techniques also hold promise for many of our forthcoming indicators.

Integrative approaches

In addition to trying to understand dynamics of indicators individually, we also envision use of approaches that incorporate many response variables simultaneously. Generally, these approaches either a) concatenate all of the information into a unitless index, or b) try to differentiate between or illustrate relationships among sampling units in a holistic, multivariate sense. Examples of the former approach we are most likely to use include calculation of beta and gamma diversity from alpha diversity across sampling locations, the portfolio of diversity indices available (Magurran 1988), and a floristic quality assessment (Swink and Wilhelm 1994).

The second approach may involve an array of tests, depending on the nature of the data being analyzed. For continuous abiotic properties, two or more types of sites can be compared to determine whether the site types differ in values across all (or many) properties in a multivariate analysis of variance (MANOVA) or, if assumptions are not met, in a nonparametric MANOVA (NPMANOVA). If, instead, the data are abundance or cover or even presence of species at a collection of sites, ordination of the sites in multidimensional space can shed light on the relationships among sites in terms of their species composition. These ordination techniques are needed because of the 'dust-bunny' distribution of species at and across sites, namely, that few species are dominant at any site and instead most species are uncommon or totally absent (McCune and Grace 2002).

Many analytical tools are available to answer a number of specific multivariate questions, and theory and analytical algorithms continue to be developed to address hypotheses from increasingly complex designs. We will rely largely on PC-ORD (McCune and Grace 2002) to analyze community-wide questions; nonmetric multidimensional scaling (NMS) is currently one preferred test. These techniques also lend themselves to tracking of community composition at sites through time, as illustrated by West and Yorks (2002), vector change analyses (Fulton and Harcombe 2002) and replicate *G*-tests (Rooney et al. 2004) for plants. Some authors (Anderson et al. 2001, Rexstad et al. 1988) have posited that many common multivariate techniques have high probability of producing spurious results; however, these critiques are leveled more at the tendency of practitioners to extend inference beyond the analysis rather than at robustness of the tests themselves.

Bayesian approaches

As an alternative to so-called frequentist statistics, Bayesian statistical methods have gained increasing popularity among biometricians (Dorazio and Johnson 2003). In brief, Bayesian approaches quantify pre-existing knowledge or beliefs about the system into what is known as a prior probability distribution. In Bayes' theorem, those existing beliefs are updated as a result of new monitoring data, which produce revised beliefs that are quantified in a probability distribution *a posteriori*. This approach is attractive not only because it allows an informed starting point, but also because it allows a more direct assessment and portrayal about the truth of the hypothesis, rather than relying on a subjective threshold (P-value) that determines acceptance or rejection. In spite of this, the utility of Bayesian statistics in monitoring efforts such as ours seems limited until extensive (> 30 years) data sets are accumulated or unless the Network were to adopt a model-based approach to inference.

Approaches to increase the confidence in and robustness of our findings

QA/QC process

Of the various approaches we plan to adopt, the simplest involves the identification of errors in data collection or recording, data entry, and data transmission. Correction of these errors will lead to greater accuracy and statistical power in tests. Chapter 6 details how we intend to limit such errors.

Testing for observer bias

As mentioned in Chapter 4, observer bias can account for up to 50% of the variability in a response variable. We will test for such biases, and apply correction factors as necessary. To pre-empt such errors, we will train observers before and check their performance in the middle of field season, provide explicit methodological instructions that minimize or eliminate subjective decisions in the field, take voucher specimens (especially plants) or record calls for species that cannot be unequivocally identified, and may use self-correcting methods such as paired-observer variable circular plots for bird surveys (Kissling and Garton 2006) in the near future.

Reduction of sampling error

We will use the various approaches mentioned in Chapter 4 to reduce sampling error in our assessment of change over time in indicators. Unfortunately, it is rarely possible to estimate parameters without some sampling error. Thus, in addition to the true environmental variability that exists over space and time (and is consequently reflected in monitoring measurements), there is also sampling error associated with the measurements. Distinguishing measurement error from real changes in the environment is sometimes difficult, because estimation of 'sampling variance' includes an element of both of these types of error, which are highly confounded. We will attempt to use current or emerging approaches to partition parameter (process) variation from sampling error, through their explicit specification in models that reflect the sampling design. Process variation includes not only temporal variability (e.g., diel as well as within- and among-year variation), but also demographic, spatial, and individual variation.

Avoidance of spurious results

Spurious results are those that are interpreted statistically to indicate an apparently meaningful effect or relationship, but that do not reflect an actual biological phenomenon. The risk of finding such results is greatest when monitoring analyses are not driven by specific objectives determined beforehand, but instead consist of large numbers of exploratory analyses (also called 'data dredging') to find something 'significant' (Anderson et al. 2001, 2000). Such exploratory analyses can be used to identify possible relationships that may warrant further investigation. Problems arise, however, when such analyses are used to test rather than generate hypotheses, and when investigators overstate the biological importance of the test (Eberhardt 2003, Anderson et al. 2001, Cherry 1998, Yoccoz 1991). Two particular analytical techniques that may produce spurious results are stepwise regression and comparison of all possible subsets of models.

Over-reliance on null hypothesis testing to assess significance of results has been increasingly criticized for several reasons. First, nearly all null hypotheses are false on *a priori* grounds (leading to their being termed 'silly nulls'), and rejecting a null hypothesis often does not provide useful insights for management, conservation, planning, or further research (Anderson et al. 2000, Johnson 1995, Savage 1957). Second, arbitrary selection and blind adherence to a specific α-level (e.g., 0.05) that demarcates finding vs. not finding an effect is relatively uninformative biologically and may not reflect the investigators' perceived consequences of Type I and Type II errors (Field et al. 2005, Cherry 1998). Third, *P*-values are dependent on sample size, such that it is always possible to reject a null hypothesis with a sufficiently large sample size, regardless of how trivially small the true difference is. Fourth, *P*-values do not provide information about the magnitude or the precision of an estimated effect. Fifth, *P*-values cannot be used as evidence to accept the null hypothesis, only to fail to reject it. *P*-values indicate the probability of obtaining the data collected, given the null hypothesis, rather than the probability that the null hypothesis (e.g., no change in an indicator) is true given the data (Anderson et al. 2000).

Testing of analytical assumptions

In addition to the fact that certain analyses are not appropriate or easily interpretable when assumptions are not met, the use of appropriate analyses are often a more powerful approach (Sokal and Rohlf 1995, but see Johnson 1995). Two examples are the existence of a particular distributional shape (e.g., normal, Poisson) and the presence of significant interaction between factors. Analyses will be modified appropriately when assumptions are not met.

Consideration of sample sizes

As mentioned above, if we find that variability in a given response variable across our sampling domain is greater than what was estimated or found in previous studies, we will increase our sample size. GRTS-based approaches allow such additions (as well as deletions), yet still maintain a spatially balanced design. Alternatively, if we find that more samples are needed to accomplish our monitoring goals and additional sampling locations cannot be selected for logistical or financial reasons, we will either abandon sampling of that particular response variable or give it less attention analytically.

Reporting and Communications

A primary goal of the NPS Servicewide I&M Program is to ensure that the results and knowledge gleaned are shared with all appropriate parties, especially the parks and their natural resource managers. Because the Network's main focus is to assist parks with monitoring needs, we will strive to provide park managers with clear, meaningful products to convey our findings.

While the Network primarily addresses concerns of the parks, its monitoring program has the potential to serve a much broader community. For example, monitoring projects can provide a starting point for external scientific research (especially to establish cause-effect relationships), and can provide insights for adaptive management on other public lands. The Network is also accountable to multiple organizations within the federal government, including the NPS I&M Program and the U.S. Congress. To provide accountability and to meet the requests of all parties, we will provide multiple types of reports and communications. These are described below, and summarized in Table 7.2.

Written Reports

Annual summary reports

Summary reports will be produced annually for each Vital Sign monitored during the previous year, with the primary audience being the parks. These summaries will be communications to document our efforts and convey the findings of the previous field season. At a minimum they will provide:

- a brief introduction that describes why that Vital Sign is being monitored,
- an outline of the sampling strategy, including the number of sites sampled, parameters measured, and analyses performed,
- data summaries, including tables and figures to enhance visual presentation, as well as a text explanation of the findings,
- any other relevant or significant findings,
- a limited discussion section in which important results are interpreted.

Drafts of annual summary reports will be completed by January 15 for internal review. The final reports will be provided to parks on March 1 of the year following the monitoring.

Analysis and synthesis reports

Detailed reports in which data are analyzed and synthesized will be produced on a periodic basis, with the frequency depending on the given Vital Sign (e.g., on the re-visit strategy and frequency). They will be written in the format of a scientific journal article (abstract, introduction, methods, results, discussion, literature cited) and will contain in-depth analyses as outlined in the protocol. Further, these comprehensive reports will:

- place the observed results in both a regional and historical context by relating them to other published literature,
- integrate the findings with those of other protocols
- discuss the significance of the results in terms of environmental change,
- provide management recommendations based on the findings.

The target audience of the analysis and synthesis reports will be the parks, the Network, both regional and Servicewide I&M, and the broader scientific community. Drafts will be completed by January 31 of the appointed year with a minimum of three years of data and at least every 10 years (see individual protocols for detailed schedules). These drafts will be reviewed internally and sent to the parks, and possibly outside sources, for further review. The extent of review will depend on how analytically complicated the methods are and the gravity of inference and recommendations. The final reports will be due on April 1 of the year following the monitoring.

Scientific journal articles

Because the protocols are being designed with rigorous standards of sampling design and analysis, monitoring results are expected to be highly defensible and meet the

Table 7.2. Summary table of reports and communications produced by the Great Lakes Network.

Type of Report	Purpose of Report	Primary Audience	Frequency	Review Process
Annual Summary Reports	Describe the Vital Sign being monitored; outline the sampling strategy and analyses; summarize data; present a limited discussion	Superintendents, park biologists and natural resource managers	Annual; published each March 1	Network and park level
Analysis and Synthesis Reports	Provide in-depth analyses, relate results to other published literature; relate results to other Vital Signs, discuss results in terms of environmental change; provide management recommendations	Park biologists, natural resource managers, scientific community, park superintendents	Periodic (every 2 – 5 years, depending on Vital Sign; published April 1	Network, park, and non-NPS peer scientists
Scientific journal articles	Provide in-depth analyses, relate results to other published literature; discuss results in terms of environmental change; provide management recommendations	Scientific community	Periodic, depending on Vital Sign and strength of findings	Juried by journal editor and anonymous peer scientists
Annual Administrative Report and Work Plan	Detail accomplishments of previous year; present objectives for upcoming year; account for Network spending	Inventory & Monitoring Network, Park Service administration	Annual	Network and park level
Briefings to park biologists and managers	Present findings from previous year; Provide synopsis of monitoring results and management considerations	Park biologists and natural resource managers	Annual	Network level
Conference presentations	Provide in-depth analyses, relate results to other published literature; discuss results in terms of environmental change; provide management recommendations	Scientific community	Periodic, depending on Vital Sign and strength of findings	Network level
Extension and outreach -Fact Sheets -Bulletins	Summarize monitoring results, highlighting key findings for a broad audience	General public, NPS administrators and other Divisions, scientific community	Periodic, as the need arises	Network level and with Great Lakes Research and Education Center
Website	Varies, depending on report and Vital Sign	Varies, but includes parks, scientists, and the general public	Periodic	Network level

standards of the peer-review process. The publication of monitoring results in scientific journals will allow the Network to reach the scientific community in a way that internal NPS reports cannot. Further, peer-reviewed publications can promote collaborative investigation by members of the scientific community, either independently or in cooperation with the Network. Ultimately, this process should foster a greater understanding of ecosystem components and processes. For these reasons, the Great Lakes Network will strive to publish analysis and synthesis reports in peer-reviewed scientific journals. We will encourage the preparation of manuscripts by having reviewers of analysis and syntheses reports recommend whether publication is warranted and suggest appropriate journals. The quantitative ecologist and network coordinator will track these recommendations and encourage and provide work time respectively.

Annual administrative report and work plan
This administrative report is produced by the Network every November. It details the accomplishments of the previous fiscal year, presents the objectives for the following fiscal year, and accounts for Network spending. The report is submitted to the Servicewide I&M Program which, in turn, uses it to develop a national report on NPS inventory and monitoring efforts. Because this report is reviewed by both the national program and the U.S. Congress, we must be inclusive yet briefly highlight key findings in a clear and concise manner that is understandable to those without a scientific background.

Other Communications

While reports are a definitive method of documenting the progress of each program, other means of communication can further disseminate information to a broader audience. To this end, we will provide the following additional types of communications:

Briefings to park biologists

Each project manager will present the findings from his or her program to the biologists from the parks in which monitoring was conducted the previous year. These presentations, which will likely occur at the annual technical committee meeting in March, will provide a concise synopsis of monitoring results as well as management considerations.

Conference presentations

When possible, project managers will present monitoring results at regional and national scientific conferences. This will allow the Network to reach the broader scientific community, as well as land managers and conservation practitioners. Potential conferences include those sponsored by the Ecological Society of America, Society for Conservation Biology, The Wildlife Society, the International Association for Landscape Ecology, the Natural Areas Association, and the George Wright Society. At a more local scale, the Western Great Lakes Research Conference, which is sponsored in part by the Network, is a valuable venue for information exchange.

Extension and outreach

Outreach is the primary conduit by which the Network will reach policy makers, educators, and the general public. We are working cooperatively with Minnesota Sea Grant to develop general information articles and fact sheets targeted for handouts to the public, print in local newspapers and regional magazines. These articles will describe the mission of the I&M Program. Upon completion of one to two years of monitoring, the Network plans to publicize the program via radio outlets (e.g., Wisconsin Public Radio) and regional magazines. Additional periodic opportunities may arise that will allow us to reach the target group above, including participating in the activities of the International Joint Commission, SOLEC (State Of the Lakes Ecosystem Conference), and CoastWatch.

We also wish to ensure effective communication with the general public in the parks. We will develop a series of 'talking points' to explain our program and activities when we encounter the public at parks. We will also provide information to park interpretive staff so that they can explain the activities and findings of the I&M Program. In large part, this latter goal will be accomplished by working with staff from the Great Lakes Research and Education Center stationed at Indiana Dunes National Lakeshore.

Website

The Network's website (www.nature.nps.gov/im/units/glkn/index.htm) is the primary means of communicating information about our activities and findings. We have developed the website so that it is informative both to individuals outside of the Park Service as well as those with a large degree of familiarity with the I&M Program. A section of the Network's website, which is still under development, will be map-based using an Internet Mapping Service (IMS) to provide access to spatially explicit data and allow users to explore Network data in a spatial context. The Network's IMS website will allow users to query and download data for use on local computers. In addition to the standard internet site and IMS site, we will develop an intranet page to disseminate materials to others within the Park Service. All Network products are available for download from the site.

Chapter 8 – Administration and Oversight

This chapter describes the administrative components of the Great Lakes Network monitoring program including the overall decision-making processes; facilities; partnerships; and oversight by client parks, the regional office, and the Servicewide I&M Program.

The Network's Role and Function

Each of the nine parks in the Network is responsible for conducting natural resource inventories, monitoring, research, and management activities; however, the Network is responsible for monitoring and reporting on a core subset of ecosystem indicators for each park (see Chapter 3). The Network program must adhere to national I&M standards for scientific rigor, data management, and reporting. The Network is accountable to the nine parks, the Midwest regional office, and ultimately to the Servicewide I&M Program and Water Resource Division (WRD), both of which provide funding and guidance. Network employees facilitate and coordinate the planning, design, field collection, and reporting of data on the core set of indicators with support and advice from the parks, regional and Servicewide I&M and WRD staff, and the scientific community.

Decision-making Structure

The Network has an 11-member Technical Committee (hereafter "Committee") with representation from each of the nine parks, the Midwest regional office, and the Network office. The Committee meets in person each spring, and via email or teleconference as needed, to discuss and make decisions on the technical aspects of the program. The Network's coordinator serves as the chair of the Committee and other Network and park employees attend meetings as needed. For decisions on hiring of permanent staff, significant allocations of funds, or the overall direction of the program, the Committee makes recommendations to a six-member Board of Directors. The Board of Directors consists of four of the nine park superintendents and the regional and Network I&M coordinators. Superintendents on the Board rotate on a four year basis to provide equal representation of parks over time. The Board meets each fall to assess progress and review the annual work plan. The Board also conducts business electronically or via teleconference on an as-needed basis. Final authority on the overall program rests with the Board, albeit in accordance with regional review processes and the National I&M Program standards. The bylaws and decision-making process of the Technical Committee and Board of Directors are detailed in a Charter signed by all superintendents from the nine parks (Appendix A, Supplemental Document 9).

Staffing Plan

The Network coordinator is administratively supervised by the Midwest regional I&M coordinator with substantial input and consensus from the Technical Committee and Board of Directors (Figure 8.1). The Network coordinator currently supervises six permanent employees, two of whom are shared with another NPS program or a park, and five term employees. Permanent employees who work full time for the Network include the coordinator, data manager, GIS specialist, aquatic ecologist, and quantitative ecologist. Our permanent administrative assistant and a term data specialist are shared with the NPS Great Lakes Exotic Plant Management Team (EPMT), which is co-located with the Network. The permanent information technologist is shared with APIS. A term inventory specialist has worked fulltime to help complete inventory products but this position will be phased out in July of 2008. Three data specialists stationed in parks (MISS, PIRO, and VOYA) are term and subject to furlough.

The three term data specialists who are stationed in parks provide assistance to all nine parks for cataloging natural resource literature and datasets and are also helping implement monitoring in 2006 and 2007. They have a good understanding of park logistics and are invaluable for coordinating field activities and carrying out certain monitoring efforts. Their connection with the parks will be especially useful during the initial two years of implementation. These term positions will end midway through the 2007 field season, but may be extended two more years. We are assessing our protocol-specific costs and needs for expertise following completion of the 2006 field season. Network staff will meet with the Technical Committee and Board of Directors during winter 2006/07 to consider future positions including permanent and temporary (i.e. term appointments and summer seasonal staff).

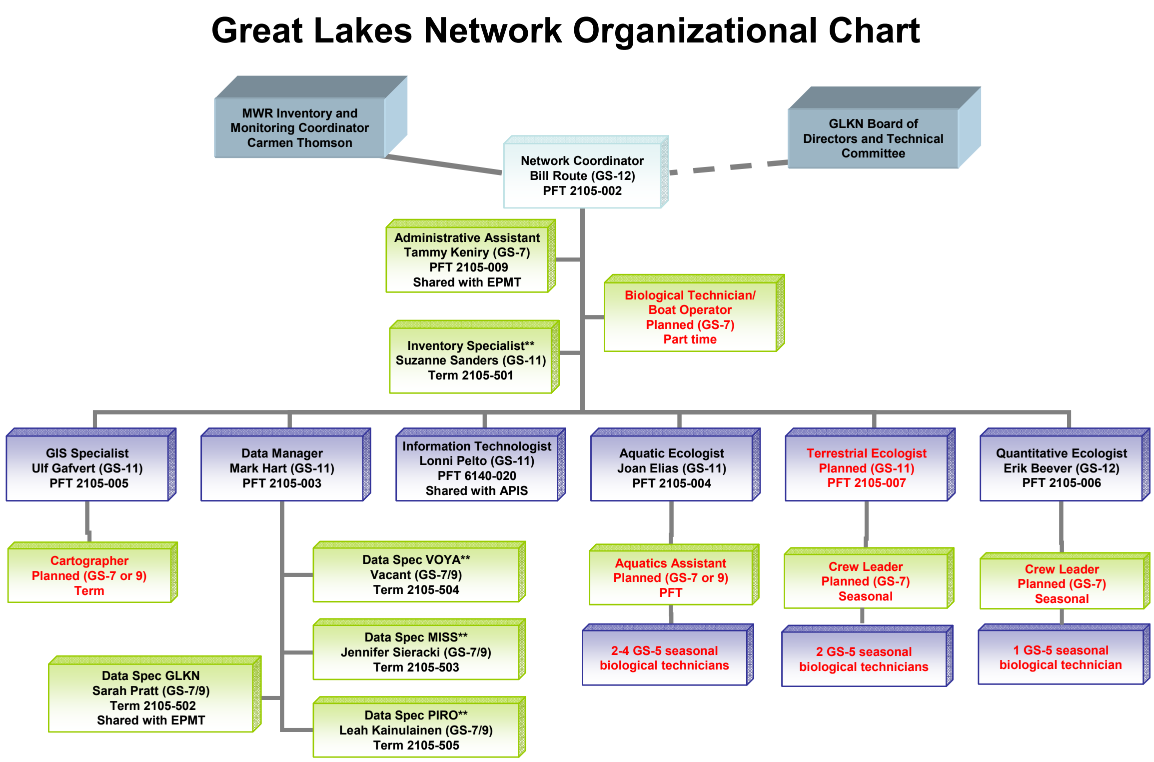


Figure 8.1 Organizational chart for the Great Lakes Inventory and Monitoring Network. Positions in red are proposed new positions and those marked with ** are proposed for being phased out.

Proposed future positions, which will be discussed at future Committee and Board meetings, include a permanent GS-11 terrestrial ecologist (vegetation background), permanent GS-7 or 9 assistant aquatic ecologist, term GS-7 or 9 cartographer, part time GS-7 biological technician/boat operator, and several GS-5 and GS-7 summer biological technicians to carry out fieldwork. In some cases, these positions may stationed in parks, shared with parks or other NPS programs, or shared between protocol teams.

ADMINISTRATIVE SUPPORT AND FACILITIES

The Great Lakes Network office is located in Ashland, Wisconsin, which is centrally located among Network parks (Figure 8.2). The office is co-located with the U.S. Geological Survey Lake Superior Biological Station, the U.S. Fish & Wildlife Service (FWS) Office of Fisheries Assistance, and the Great Lakes EPMT. The Network and the EPMT currently share two staff positions (explained above) and office space. The suite occupied by the GLKN and EPMT has a laboratory, a server/plotter room, a small library, and a conference room shared with USGS and FWS.

Also in Ashland is the Northern Great Lakes Visitor Center, a multi-agency interpretive center co-sponsored by NPS, which has several meeting/conference rooms and a large auditorium for conferences. Ashland hosts Northland Community College, the Wisconsin Indianhead Technical College, and the Sigurd Olson Environmental Institute. All are higher learning centers that provide GLKN access to students and faculty for conducting a variety of natural resource and administrative functions.

Several parks around the Network have laboratories for basic water quality work (Figure 8.2). The St. Croix Watershed Research Station (SCWRS), White Water Associates, and Natural Resource Research Institute (NRRI) have laboratories for analysis of water chemistry. Herbaria for terrestrial plant identification are located in several parks and universities around the region.

Daily administrative functions are carried out by the Network's administrative assistant, with most contracting, personnel actions, and administrative oversight provided by APIS under a Memorandum of Understanding. Some contracting services are provided by other parks or the regional office when a higher-warranted officer is needed or if an activity is specific to one park.

PARTNERSHIPS

The Great Lakes Network has built collaborative relationships with several universities, agencies, and institutions – too many to mention here. Many of these partnerships were the result of the inventory process (Route 2000) and the early phases of developing this monitoring program. For example, six universities and three federal agencies were involved in developing the first set of six protocols. We will continue to maintain or expand many of these relationships over the next six years (Table 8.1).

The parks in the Network will continue to be the primary partners of the program. Park natural resource staff provide logistical support and in some cases help collect data. We are also working closely with the Northern Forest Great Lakes Cooperative Ecosystems Studies Unit (CESU), the Great Lakes Research and Education Center (GLREC), and the Great Lakes Exotic Plants Management Team (EPMT) to coordinate the annual Western Great Lakes Research Conference. The conference serves as a forum for the Network, parks, and other partners to report on research as well as inventory and monitoring projects in the nine parks.

The CESU will continue to be a major partner in identifying researchers who can assist in the development of protocols and the analysis of resulting data and the GLREC will also help in this role. In addition, the GLREC, along with Minnesota Sea Grant, will play an increasing important role in making the information generated by the Network program publicly available in park kiosks, bulletins, news articles, and regional magazines.

Four NPS Midwest Regional employees, who are stationed in parks of the Great Lakes Network, have been and will continue to be major contributors and partners in the program. They are subject experts in aquatic ecology, fisheries, wildlife, and air resources.

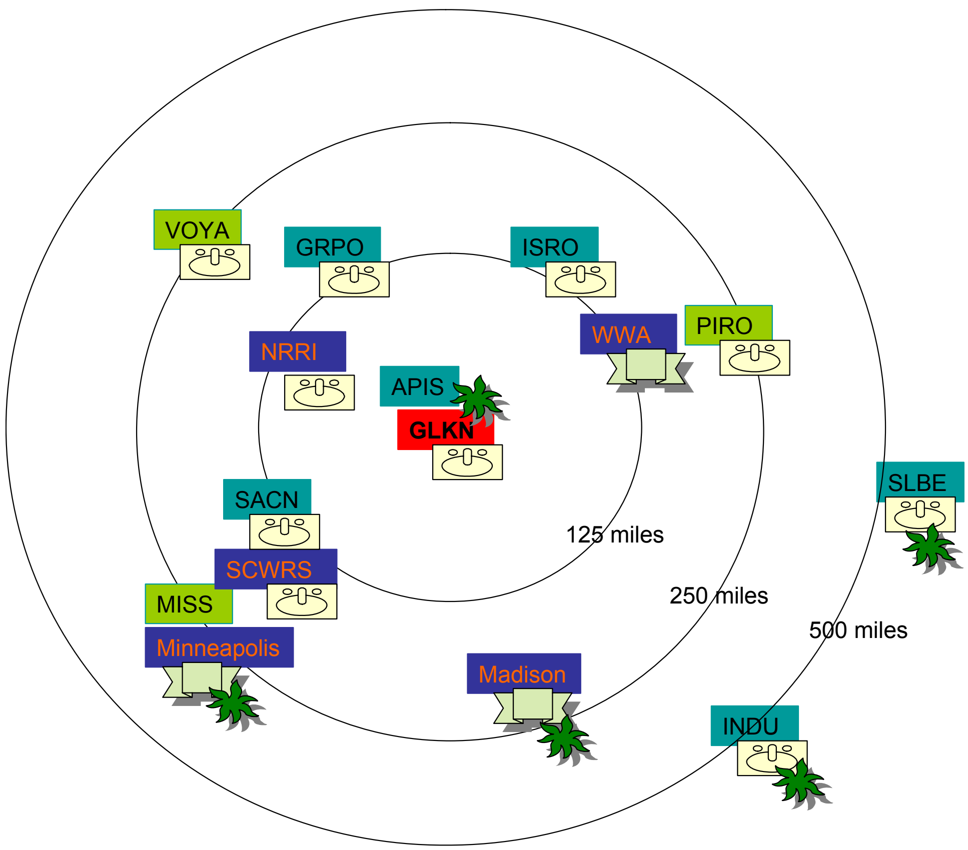


Figure 8.2. Graphical representation of distance (miles by vehicle) between the Great Lakes Network office, the nine parks, and other important partners with facilities. Parks colored bright green currently host a Network employee; sink = laboratory, plant = herbarium, ribbon = certified water quality lab; see Table 1.4 for park acronyms; WWA = White Water Associates, SCWRS = St Croix Watershed Research Station; NRRI = Natural Resource Research Institute.

Programmatic and Science Review

The Annual Administrative Report and Work Plan (AARWP) documents program development, discloses expenditures, presents summary results, and proposes future directions (see Chapter 7). The Western Great Lakes Research Conference provides a forum for presenting results, discussing issues, and making recommendations. The Technical Committee meeting is held in conjunction with the conference and together, they provide an opportunity for client parks and science partners to review and evaluate the program each year. The Board of Directors meets each fall providing further opportunity to review and act on recommendations.

The Network will undergo a thorough review three years following implementation of the first monitoring protocols. Hence, with implementation expected in 2006, the first full programmatic and science review will occur in 2009. This review will be overseen by the national and regional I&M coordinators. The review will include oral or poster presentations by Network staff and collaborators on the methods, results, and management implications of data from each protocol and for the integrated program as a whole. A panel of NPS and outside scientists, selected by the regional and national I&M coordinators, will critically review the entire program and make recommendations for phasing out or modifying various efforts. This science review will include data archival and transfer processes and will be followed by an audit of the financial records and administrative processes. The financial audit will be conducted by administrative staff from the Network parks and Midwest region. Recommendations from this programmatic and science review will be advanced to the Technical Committee and Board of Directors for final recommendations and action.

Table 8.1. Partnerships in addition to client parks that will be important for long-term monitoring of Vital Signs in the Great Lakes Inventory and Monitoring Network.

Partner	Relationship for future monitoring
Canadian Fish & Wildlife Service	Will conduct lab analysis of eggs from herring gulls for contaminants under bioaccumulative contaminants protocol
Cooperative Ecosystem Studies Unit	Co-host of annual Western Great Lakes Research conference; help find academic investigators to analyze and review program findings
Colorado State University	Develop and maintain the Network's web-based ArcIMS data service
EPA, Great Lakes National Program Office	Co-testing, and possible future implementation, of amphibian monitoring methods in parks along the Lake Superior shoreline
Exotic Plant Management Team	Continue sharing office facilities and staff; shared responsibility for implementing invasive plant monitoring
Great Lakes Research and Education Center	Co-host of annual Western Great Lakes Research conference; ; assist with integrating findings with park interpretive staff, park managers, and public
Michigan Department of Environmental Quality	Co-funding of collection and lab analysis of bald eagle blood for contaminants at Michigan parks (PIRO, SLBE, and ISRO)
Minnesota Department of Natural Resources	Assist with land cover/land use monitoring for MISS corridor and collaborate on bioaccumulative contaminants monitoring
Minnesota Sea Grant, University of Minnesota	Collaborates with the Network and Great Lakes Research and Education Center to provide public outreach via fact sheets, news releases, and feature articles for natural resource magazines and our web site
Natural Resource Research Institute, University of Minnesota	NRRI staff helped with program development including being on the Science Advisory Group, collaborated on the overall sampling framework, and helped develop several protocols; we expect continued involvement in project-specific monitoring activities, data analysis, and science review
Northland Community College and Sigurd Olson Environmental Institute	Maintain a Cooperative Agreement to use faculty and students to help implement monitoring in parks
NPS National Vegetation Mapping Program	Continue funding vegetation mapping program through 2011 and the completion of all Network parks
St. Croix Watershed Research Station	Long-term analysis and interpretation of diatom community composition
University of Wisconsin, Madison	Potential collaboration on analysis of vegetation monitoring data; joint development of land cover/ land use (LCLU) protocol and possible future role in analysis and maintenance of LCLU data
US Forest Service, Forest Inventory and Analysis program	Joint training for vegetation monitoring staff each year; data sharing including plot locations and all plot data after quality control / quality assurance has been conducted
USGS Amphibian Research and Monitoring Initiative	Possible partner for analysis and reporting of monitoring data and annual training for amphibian monitoring crews
USGS Water Resource Division	Continue an Interagency Agreement to collect and provide web access to stream gage data
Wisconsin Department of Natural Resources	Cooperative Agreement to collaborate on bioaccumulative contaminants monitoring and co-develop a landbird training and certification web site

Chapter 9 – Schedule

The implementation schedule for all Vital Signs was presented in Chapter 5. In this chapter we present the seasonal sampling periods and annual revisit rates for each park for the first ten protocols we intend to implement in 2006 and 2007. Data collection will occur primarily during the snow-free months of April through October, although climate and air quality data will be acquired throughout the year (Table 9.1). Schedules are closely tied to the monitoring questions and biology of the resources being monitored; however, within-year schedules also depend on access and other logistical constraints.

Seasonal Phenology

In some cases, the timing of monitoring will depend on phenological differences among parks. Spring comes earlier and summers are longer in the more southerly parks, such as INDU and MISS. Thus, we will begin calling surveys for amphibians in southern parks and move north. Similarly, vegetation monitoring will need to be scheduled in each park to ensure spring green-up has occurred so that ground flora can be found and identified. Conversely, winter comes early and stays longer in northern parks and schedules will have to account for the relatively shorter field season. Parks that are on the Great Lakes generally have moderated weather patterns which can retard spring green-up and dampen extremes in summer heat and winter cold. Several parks receive lake effect precipitation, which may also affect the timing of some monitoring activities.

Scheduled Training

Each protocol will have a standard operating procedure for any training or certification requirements. Some training will occur days, or even weeks, before the field season begins, while other training will occur during the initial days of field work. Training and certification for identifying landbirds will be accomplished through a web site being co-developed with the Wisconsin Department of Natural Resources for identifying birds is being developed to help make monitoring more consistent and to document observer abilities. However, training for terrestrial vegetation will be scheduled differently. In this case, most of the training will be incorporated into the initial days of monitoring with an experienced field botanist.

Field work that requires crew members to operate water craft will require boat training and certification. We will normally get logistical support from the park or take public transportation at APIS, SLBE, and ISRO where large boats are required to navigate the Great Lakes. However, to reduce dependence on park staff, we will be trained and certified to use small boats (16’ to 20’) and/or canoes on inland lakes and rivers. This training will be scheduled prior to the field season at one of the nearest parks.

Table 9.1. Generalized seasonal schedule for collecting monitoring data for each of the initial ten protocols planned for implementation in the Great Lakes Inventory and Monitoring Network parks in 2006 and 2007. A "T" in a cell denotes timing of training for staff. Specific dates can be found in individual protocols and SOPs.

Protocol	Sample type	January	February	March	April	May	June	July	August	September	October	November	December
Climate	Acquisition/upload												
Air quality	Acquisition/upload												
Land birds	Point counts					T							
Bioaccumulative contaminants	Bald eagle tissue												
	Herring gull eggs												
Water quality for large rivers	Chemistry and flow		T										
Water quality for inland lakes	Chemistry and			T									
Amphibians	Calling surveys				T								
	Daytime searches				T								
Terrestrial vegetation and soils	Composition and structure					T							
	Deer browse					T							
Land cover/land use (coarse and fine scale)	Aerial flights												

Scheduling with Park Staff

Access to certain parks is greatly limited by the size and associated dangers of traveling by boat on the Great Lakes. In particular, APIS, ISRO, and to a lesser degree, SLBE pose a challenge in getting to and from sampling sites. For access to these parks we have purchased a 21 foot twin engine boat and will need to either hire a part time boat operator, use park staff who are certified operators, or get Network staff certified as operators. For smaller craft we will schedule boat transportation with park staff or find public transportation such as ferries. To ensure our logistical needs are understood and the parks have ample opportunity to fit our program into their work load, we will send out a "Preliminary Monitoring Schedule and Request for Support" letter to each park in late February every year. This notice and request for assistance will give each park our best estimates of dates, number of observers, and needs for transportation, housing, and other facilities required for the year. A second "Final Monitoring Schedule and Support Needs" letter will be sent in April each year to provide final estimates and additional detail such as the specific location of sites to be visited. These preliminary and final requests should allow parks adequate time for scheduling and assessing whether our needs can indeed be met. It will also limit the number of contacts each park must have regarding scheduling events with Network staff.

Park-specific Sampling

Revisit schedules are covered more thoroughly in Chapter 4 and in each protocol; however, it is worth noting here that in addition to the statistical rationale behind revisit designs for each protocol, we have attempted to spread annual sampling among the parks (Table 9.2). Reasons for dispersing sampling effort among parks include: 1) it reduces the chance of overloading a single park's ability to meet our transportation and facility requests, 2) it increases park support for our program when some monitoring occurs in their park each year, 3) in some cases it allows us to take advantage of park proximity to reduce travel costs, and 4) it was necessary to mix logistically challenging (and thus costly) parks with those that are more accessible to stay within budget. In the initial two years, the Network will be conducting field work (excluding data acquisition for air and weather) in connection with as many as six protocols in each park (Table 9.2).

The rotation, or revisit rate, for each protocol across the six planning years can be seen more clearly in Table 9.3. The revisit schedule is a balance between the cost of sampling and the need for repeated visits to provide statistical rigor (see Chapter 4). We are attempting to coordinate terrestrial vegetation monitoring on the ground with remote sensing efforts for the land cover/ land use monitoring (Tables 9.2 and 9.3). However, data collection for the land cover/ land use protocol will likely consist of aerial photography flights in both fall and spring, which is a major expense. We may choose to utilize other available photography, often flown by states and other municipalities, when it meets our criteria and if it is within a 1-4 year window around our target year. Thus the occurrence of aerial flights shown on Tables 9.2 and 9.3 is a target year with bounds of 1-4 years.

Table 9.2. Annual occurrence of monitoring (by park) for the first ten protocols, 2006-2011.

2006

Protocol	Sample type	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Climate	Acquisition/upload	•	•	•	•	•	•	•	•	•
Air quality	Acquisition/upload	•	•	•	•	•	•	•	•	•
Land birds	Point counts	•	•	•	•	•		•	•	•
Bioaccumulative contaminents	Bald eagles	X			X[1]	X	X[1]	X	X[1]	X[1]
	Herring gulls	X			X[1]				X[1]	X
Water quality (lakes or rivers)	Core and advanced			X		X				X
Amphibians	Calling surveys	X					X[2]		X	
	Daytime searches	X					X[2]		X	
Terrestrial vegetation and soils	Composition and structure									
	Deer browse									
Land cover/land use	Aerial flights									

2007

Protocol	Sample type	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Climate	Acquisition/upload	•	•	•	•	•	•	•	•	•
Air quality	Acquisition/upload	•	•	•	•	•	•	•	•	•
Land birds	Point counts	•	•	•	•	•		•	•	•
Bioaccumulative contaminents	Bald eagles	X			X[1]	X	X[1]	X	X[1]	X[1]
	Herring gulls	X			X[1]				X[1]	X
Water quality (lakes or rivers)	Core and advanced	X		X	X		X	X	X	X
Amphibians	Calling surveys	X[2]			X	X			X	
	Daytime searches	X[2]			X	X			X	
Terrestrial vegetation	Composition and structure		X	X				X		
	Deer browse		X	X				X		
Land cover/land use	Aerial flights		X	X				X		

2008

Protocol	Sample type	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Climate	Acquisition/upload	•	•	•	•	•	•	•	•	•
Air quality	Acquisition/upload	•	•	•	•	•	•	•	•	•
Land birds	Point counts	•	•	•	•	•	•	•	•	•
Bioaccumulative contaminents	Bald eagles						X[1]		X[1]	X[1]
	Herring gulls				X[1]				X[1]	
	Species TBD		X	X						
Water quality (lakes or rivers)	Core and advanced	X	X	X	X	X	X		X	X
Amphibians	Calling surveys		X	X			X	X		
	Daytime searches			X				X		X
Terrestrial vegetation	Composition and structure									X
	Deer browse									X
Land cover/land use	Aerial flights									X

Table 9.2. Continued.

2009

Protocol	Sample type	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Climate	Acquisition/upload	•	•	•	•	•	•	•	•	•
Air quality	Acquisition/upload	•	•	•	•	•	•	•	•	•
Land birds	Point counts	•	•	•	•	•	•	•	•	•
Bioaccumulative contaminents	Bald eagles						X[1]		X[1]	X[1]
	Herring gulls				X[1]				X[1]	
	Species TBD		X	X						
Water quality (lakes or rivers)	Core and advanced	X	X	X	X		X	X	X	X
Amphibians	Calling surveys				X	X			X	
	Daytime searches	X			X	X				
Terrestrial vegetation	Composition and structure				X					
	Deer browse				X					
Land cover/land use	Aerial flights				X					

2010

Protocol	Sample type	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Climate	Acquisition/upload	•	•	•	•	•	•	•	•	•
Air quality	Acquisition/upload	•	•	•	•	•	•	•	•	•
Land birds	Point counts	•	•	•	•	•	•	•	•	•
Bioaccumulative contaminents	Bald eagles	X			X[1]	X	X[1]	X	X[1]	X[1]
	Herring gulls	X			X[1]				X[1]	X
	Species TBD									
Water quality (lakes or rivers)	Core and advanced	X	X	X	X	X	X		X	X
Amphibians	Calling surveys		X	X			X	X		
	Daytime searches			X				X		X
Terrestrial vegetation	Composition and structure						X		X	
	Deer browse						X		X	
Land cover/land use	Aerial flights						X		X	

2011

Protocol	Sample type	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Climate	Acquisition/upload	•	•	•	•	•	•	•	•	•
Air quality	Acquisition/upload	•	•	•	•	•	•	•	•	•
Land birds	Point counts	•	•	•	•	•	•	•	•	•
Bioaccumulative contaminents	Bald eagles	X			X[1]	X	X[1]	X	X[1]	X[1]
	Herring gulls	X			X[1]				X[1]	X
	Species TBD		X	X						
Water quality (lakes or rivers)	Core and advanced	X	X	X	X		X	X	X	X
Amphibians	Calling surveys				X	X			X	
	Daytime searches	X			X	X				
Terrestrial vegetation	Composition and structure	X				X				
	Deer browse	X				X				
Land cover/land use	Aerial flights	X				X				

[1] = Collaborative effort with Clemson University and Michigan Department of Environmental Quality
[2] = Collaborative effort with the Great Lakes National Program Office
X = Protocol developed, implemented, and reporting is solely by the Network.
• = The Network is collaborating with parks and others who are collecting the data; the Network will develop protocols to increases consistency, and to document methods of acquiring the data; the Network will report on the data.

Table 9.3. Revisit schedule for ten initial protocols that will be implemented by the Great Lakes Inventory and Monitoring Network - 2006 through 2011. x = initial year(s) of implementation; some change likely. **X** = full implementation expected.

Protocol	**Park**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Climate	All	x	**X**	**X**	**X**	**X**	**X**
Air Quality	All			**X**	**X**	**X**	**X**
Landbirds	VOYA	x	**X**	**X**	**X**	**X**	**X**
	GRPO	x	**X**	**X**	**X**	**X**	**X**
	ISRO	x	**X**	**X**	**X**	**X**	**X**
	APIS	x	**X**	**X**	**X**	**X**	**X**
	PIRO			**X**	**X**	**X**	**X**
	SLBE	x	**X**	**X**	**X**	**X**	**X**
	SACN	x	**X**	**X**	**X**	**X**	**X**
	MISS	x	**X**	**X**	**X**	**X**	**X**
	INDU	x	**X**	**X**	**X**	**X**	**X**
Bioaccumulative Contaminants	VOYA	x	**X**	**X**	**X**	**X**	**X**
	PIRO	x	**X**	**X**	**X**	**X**	**X**
	SLBE	x	**X**	**X**	**X**	**X**	**X**
	ISRO	x	**X**			**X**	**X**
	APIS	x	**X**			**X**	**X**
	SACN	x	**X**			**X**	**X**
	MISS						
	GRPO			x	**X**		
	INDU			x	**X**		
Water Quality for Large Rivers	MISS	x		**X**		**X**	
	SACN		x		**X**		**X**
Water Quality for Inland Lakes	VOYA	x	**X**	**X**	**X**	**X**	**X**
	INDU	x	**X**	**X**	**X**	**X**	**X**
	APIS		x	**X**	**X**	**X**	**X**
	SLBE		x	**X**	**X**	**X**	**X**
	ISRO		x	**X**	**X**	**X**	**X**
	PIRO		**X**	**X**	**X**	**X**	**X**
Amphibians	PIRO	x		**X**		**X**	
	APIS	x	x		**X**		**X**
	GRPO			**X**		**X**	
	VOYA			**X**		**X**	
	MISS		x		**X**		**X**
	INDU			**X**		**X**	
	ISRO		x		**X**		**X**
	SACN			**X**		**X**	
	SLBE	x	x		**X**		**X**
Terrestrial Vegetation	SACN		x				
	INDU		x				
	GRPO		x				
	VOYA			**X**			
	ISRO				**X**		
	SLBE					**X**	
	PIRO					**X**	
	MISS						**X**
	APIS						**X**
Land Cover/Land Use (both coarse and fine scale)	SACN		x				
	INDU		x				
	GRPO		x				
	VOYA			**X**			
	ISRO				**X**		
	SLBE					**X**	
	PIRO					**X**	
	MISS	**					**X**
	APIS						**X**

** = The Network will fund work in 2006 that reflects land cover/land use in 2003

Chapter 10 – Budget

The Great Lakes Network receives annual funding from the NPS Servicewide I&M Program (I&M) and the NPS Water Resources Division (WRD; Table 10.1). Funding has grown from $82,000 in FY2000 during the biological inventory phase to $1,742,600 in FY2005 during the planning stages of Vital Signs monitoring. Base funding was established in FY2005 with $1,289,000 from I&M and $121,278 from WRD. In 2006 I&M funding increased slightly to offset pay increases while WRD funding decreased by 1% as an across the board (ATB) reduction to all Networks. We expect funding to remain at about the 2006 level for the foreseeable future. Funding from other sources supported specific projects, including metadata training and soils mapping in FY2004 and vegetation mapping in 2005 and 2006. The Vegetation Mapping Program will continue funding vegetation maps until all nine parks are completed, currently scheduled for 2010, with annual funding averaging about $500,000 per year.

Table 10.1. Great Lakes Inventory and Monitoring Network funding for each fiscal year by source of funds.

Fiscal Year	Servicewide I&M Inventory	Servicewide I&M Vital Signs	Water Resource Division	Other Sources (non-base funding)
2000	$82,000			
2001	$245,700			
2002	$225,800	$150,000		
2003	$311,800	$811,500	$123,000	
2004	$333,600	$1,286,000	$123,000	$16,427*
2005		$1,289,000	$121,278	$422,902**
2006		$1,292,500	$120,100	$598,800**

* = NPS Servicewide Soils Mapping Program and Federal Geographic Data Committee (metadata training)
** = NPS Servicewide Vegetation Mapping Program

Provisional accounting data for expenditures during the first year of implementation (2006) are summarized by expense category in Table 10.2. (These figures are provisional because this report is being completed within days of the end of the fiscal year and the full accounting cycle has not been completed; we expect < 0.1% variation in the data). In Table 10.3 we expand the categories to provide more detail on costs for each of the initial monitoring projects. In some cases, for example lab analysis for toxics under the bioaccumulative monitoring protocol under Contracts and Agreements, expenditures in 2006 will cover all or portions of costs for 2007. Similarly, many equipment purchases under the Operations and Equipment category (IT, water quality equipment) are the result of start-up costs that will be one-time expenditures.

During the first year of implementation (2006), the Network spent about 50% of base funding on personnel, with permanent staff accounting for 32% of all expenses. The Network has worked creatively with parks and other programs to share positions and, following the recommendation of the Board of Directors, has temporarily limited permanent staff to the current 5.8 full time equivalent (FTE) positions (see Chapter 8). These limits provided financial flexibility during implementation and have allowed the Network to determine protocol specific needs before committing a greater proportion of the budget to permanent staff. In 2007 and 2008, however, we expect permanent staff wages to increase as we implement additional protocols (see Chapter 8). Pending final decisions by the Board of Directors, permanent staffing costs may increase to just under 65% of total budget by 2010.

The budget summarized in Tables 10.2 and 10.3 are for the first year of implementation for long-term monitoring, which includes some piloting of monitoring methods. We expect the budget to change considerably during the first two to five years as we apportion funds to each protocol, as costs are better understood, and as new protocols are implemented. We are currently developing a five-year projected budget plan that will consider annual increases in fixed costs (wages, utilities), estimated travel costs, and other expected expenditures.

Table 10.2. Provisional accounting data for Vital Signs monitoring by the Great Lakes Inventory and Monitoring Network in fiscal year 2006 (excludes vegetation mapping).

INCOME			
	Vital Signs Monitoring	$1,292,500	
	Water Resources Division	$120,100	
	Subtotal	**$1,412,600**	
EXPENDITURES		Total	%
	Personnel (includes non-permanent staff)	$705,220	49.9
	Contracts and Cooperative Agreements	$474,974	33.6
	Operations/Equipment	$185,850	13.2
	Travel	$43,732	3.1
	Unspent balance and reconciliation	$2,824	0.2
	Subtotal	**$1,412,600**	

Because of the substantial effort and funding directed toward information and data management during Phases 1 and 2, the Network is well positioned to manage data and make them available to parks and partners. During the first year of implementation, the Network spent approximately 35% of its resources to information/data management (Table 10.3).

Table 10.3. Provisional accounting of expenditures by the Great Lakes Inventory and Monitoring Network during the first year of Vital Signs monitoring (2006) with detail related to specific Vital Signs.

INCOME				
	Vital Signs Monitoring	$1,292,500		
	Water Resources Division	$120,100		
Total Income		**$1,412,600**		
			Data Management	
EXPENDITURES		Totals	%	$
Permanent Employees				
	Network Coordinator (GS-12)	$94,476	10%	$9,448
	Quantitative Ecologist (GS-12)	$80,788	20%	$16,158
	GIS Specialist (GS-11)	$79,907	70%	$55,935
	Aquatic Ecologist (GS-11)	$73,792	30%	$22,138
	Data Manager (GS-11)	$57,547	100%	$57,547
	IT Specialist (GS-11)	$32,084	90%	$28,876
	Administrative Technician (GS-7)	$29,955	10%	$2,996
	Administrative Support (MOU with APIS)	$7,583	0%	$0
Term Employees				
	Data Specialists, I&M portion (3, GS-9)	$146,922	80%	$117,538
	Inventory Specialist (GS-11)	$69,926	30%	$20,978
	Data Specialist, GLKN (GS-9; partial year)	$10,974	100%	$10,974
	Data Specialists, WRD portion (3, GS-9)	$8,104	30%	$2,431
Seasonal Employees				
	Water quality monitoring	$9,418	5%	$471
	Bioaccumulative monitoring	$1,170	5%	$59
Awards		$2,574		
Personnel Subtotal		**$705,220**		**$345,546**
Contracts and Agreements				
	Analysis fund projects	$125,898	30%	$37,769
	Water quality - diatoms	$71,882	10%	$7,188
	Aerial photography flights	$64,179	10%	$6,418
	Bioaccumulative - toxics lab (1.5 yrs)	$49,662	10%	$4,966
	Amphibian monitoring - NRRI, SCA	$45,915	20%	$9,183
	Water quality - analytical lab & student intern	$36,562	30%	$10,969
	Maintenance of ArcIMS site	$25,000	100%	$25,000
	Land cover/land use analysis for MISS	$11,750	10%	$1,175
	Water quality - gaging stations	$10,750	50%	$5,375
	Protocol development - QA/QC & ISRO beaver	$10,198	80%	$8,158
	Landbird training & certification web site	$8,000	10%	$800
	Bioaccumulative - climber	$7,000	0%	$0
	Vegetation monitoring - student intern	$2,887	20%	$577
	Bioaccumulative - transport & consultation	$2,120	0%	$0
	Spatial themes	$2,061	10%	$206
	Logo	$1,110	0%	$0
Contracts and Agreements Subtotal		**$474,974**		**$117,785**

Table 10.3. Continued.

Operations and equipment			
Boat, trailer, engines, equip. (for Great Lakes)	$46,146		
IT (computers, PDAs, GPSs)	$44,647	50%	$22,324
Water quality monitoring equipment	$23,107		
Assessments (MWR computer & 1% ATB)	$20,468		
Boat and trailer (for inland lakes)	$8,355		
Utilities (internet, phone)	$7,543	20%	$1,509
Library (journals, books)	$6,861		
Amphibian monitoring field equipment	$5,878		
Vehicles (GSA lease)	$5,704		
General field supplies	$4,024		
Facility modifications	$3,633		
Office supplies (all accounts)	$3,430		
Vegetation monitoring field equipment	$2,078		
Bioaccumulative monitoring field equipment	$1,802		
Boat fuel & plane (reimbursement to parks)	$1,396		
Postage	$778		
Operations and Equipment Subtotal	**$185,850**		**$23,832**
Travel by Network Staff			
Data Specialists (3, park based)	$9,835	80%	$7,868
GIS specialist	$5,329	20%	$1,066
Quantitative ecologist	$4,561		
Coordinator	$4,483		
Data manager	$4,425	80%	$3,540
Aquatic ecologist	$3,859		
Inventory specialist	$3,453		
Administrative Assistant and IT Specialist	$214		
Travel by other NPS Staff			
Water quality monitoring (park staff)	$3,092		
Technical Committee & Board of Directors	$2,279		
Vegetation mapping (WASO)	$958		
Fish monitoring meeting (park)	$427		
Seasonal quarters (Network & seasonal staff)	$818		
Travel Subtotal	**$43,732**		**$12,474**
Unspent balances & reconciliation for all accounts	$2,824		
Total all Catagories	**$1,412,600**	**35%**	**$499,637**

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Appendix A – Technical Reports and Supplemental Documents

Listed below are the technical reports and supplemental documents developed for planning and development of a long-term ecological monitoring program for the Great Lakes Inventory and Monitoring Network.

Technical Reports

Casper, G. 2004. Amphibian and Reptile Monitoring in the Great Lakes Network National Parks: Review and Recommendations. GLKN/2004/03.

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Lafrancois, B. M. and J Glase. 2005. Aquatic studies in National Parks of the Upper Great Lakes states: Past efforts and future directions. Water Resources Division Technical Report. NPS/NRWRD/NRTR-2005/334. National Park Service, Denver, Colorado.

Ledder, T. 2003. Water resource information and assessment report for the Great Lakes Inventory and Monitoring Network. National Park Service, Great Lakes Inventory and Monitoring Network, Ashland, Wisconsin. Great Lakes Network Technical Report: GLKN/2003/05.

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Lind, J. N. Danz, and J. M. Hanowski. 2005. Analysis of landbird monitoring data for National Parks in the Great Lakes Network. GLKN/2005/08.

MacLean, D. B. and L. S. Gucciardo. 2005. Vegetational Analysis of the Grand Portage National Monument from 1986-2004. GLKN/2005/07.

Maniero, T. and D. Pohlman. 2003. Air quality monitoring considerations for the Great Lakes Network parks. National Park Service, Great Lakes Inventory and Monitoring Network, Ashland, Wisconsin. Great Lakes Network Technical Report: GLKN/2003/06.

Route, B. 2003. Results of scoping workshops to identify monitoring issues for national park units in the Great Lakes Network. National Park Service, Great Lakes Inventory and Monitoring Network, Ashland, Wisconsin. Great Lakes Network Technical Report: GLKN/2003/07.

Route, B. 2004. Process and results of selecting Vital Signs for the Great Lakes Network. National Park Service, Great Lakes Inventory and Monitoring Network, Ashland, Wisconsin. Great Lakes Network Technical Report: GLKN/2004/05.

Supplemental Documents

SD 1. Summary of laws, policy, and guidance relative to ecological monitoring

SD 2. Summary information and maps of the nine parks in the Great Lakes Network

SD 3. Methods for calculating weather parameters for the Great Lakes Network parks

SD 4. Studies of terrestrial resources with literature for Great Lakes Network parks

SD 5. Unpublished reports on ecological monitoring in Great Lakes Network parks

SD 6. Database of important published literature on ecological monitoring

SD 7. Protocol development summaries

SD 8. Data management plan for the Great Lakes Network

SD 9. Charter for the Great Lakes Inventory and Monitoring Network

Appendix B – Acronyms

AARWP	Annual Administrative Work Plan
ANCOVA	Analysis of Covariance
ANS	Aquatic Nuisance Species
APIS	Apostle Islands National Lakeshore (NPS)
ARD	Air Resource Division (NPS)
ARMI	Amphibian Research and Monitoring Initiative (USGS)
BACI	Before-After-Control-Impact
BBS	Breeding Bird Survey
BCC	Bioaccumulative Contaminants of Concern
CART	Classification And Regression Trees
CASTNet	Clean Air Status and Trends Network
COOP	Cooperative Observer Network
DDE	1, 1-dichloro-2,2'-bis-*p*-chlorophenyl-ethylene
DDT	1, 1, 1 -trichloro-2, 2'-bis-p-chlorophenyl-ethane
DMP	Data Management Plan
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
EPMT	Exotic Plant Management Team (NPS)
ESRI	Environmental Systems Research Institute
FCA	Fish Consumption Advisory
FGDC	Federal Geographic Data Committee
FHM	Forest Health Monitoring
FIA	Forest Inventory and Analysis
FOIA	Freedom of Information Act
FTP	File Transfer Protocol
FWS	U.S. Fish and Wildlife Service
GAM	Generalized Additive Model
GDB	Geodatabase
GIS	Geographic Information System
GLEI	Great Lakes Ecological Indicators
GLKN	Great Lakes Inventory and Monitoring Network (NPS)

GLWQA	Great Lakes Water Quality Agreement
GPRA	Government Performance Results Act
GRPO	Grand Portage National Monument (NPS)
GRTS	Generalized Random Tessellated Stratified
I&M	Inventory and Monitoring
IMAC	Inventory and Monitoring Advisory Committee
IMPROVE	Interagency Monitoring of Protected Visual Environments
IMS	Internet Mapping Service
INDU	Indiana Dunes National Lakeshore (NPS)
ISRO	Isle Royale National Park (NPS)
IT	Information Technology
LAN	Local Area Network
LCLU	Land Cover/Land Use
LTER	Long-Term Ecological Research
MANOVA	Multivariate Analysis of Variance
MDEQ	Michigan Department of Environmental Quality
MISS	Mississippi National Riverway and Recreation Area (NPS)
MOU	Memorandum of Understanding
MMP	Marsh Monitoring Program
MPCA	Minnesota Pollution Control Agency
NAAMP	North American Amphibian Monitoring Program
NADP/NTN	National Atmospheric Deposition Program/National Trends Network
NAWQA	National Water Quality Assessment program
NBII	National Biological Information Infrastructure
NERON	NOAA’s Environmental Real-time Observation Network
NGO	Non-Governmental Organization
NMS	Nonmetric Multidimensional Scaling
NOAA	National Oceanic and Atmospheric Administration
NOAEC	No Observed Adverse (or Acute) Effects Concentration
NPMANOVA	Non-parametric Multivariate Analysis of Variance
NPOMA	National Parks Omnibus Management Act
NPS	National Park Service
NRID	Natural Resource Information Division

NRRI	Natural Resources Research Institute (U of MN - Duluth)
NVCS	National Vegetation Classification System
NWR	National Wildlife Refuge
OIRW	Outstanding International Resource Waters
ORVW	Outstanding Resource Value Waters (MN designation)
ORW	Outstanding Resource Waters (WI designation)
OSRW	Outstanding State Resource Waters (MI and IN designations)
PAH	Polycyclic Aromatic Hydrocarbons
PAO	Percent Area Occupied
PBDE	Polybrominated Diphenyl Ether
PCB	Poly-Chlorinated Biphenyls
PDS	Protocol Development Summary
PEL	Plant Ecology Lab
PFO	Perfluorooctane
PIRO	Pictured Rocks National Lakeshore (NPS)
QA/QC	Quality Assurance/Quality Control
RAWS	Remote Automated Weather Stations
RDBMS	Relational Database Management System
RMS	Root Mean Square
SACN	Saint Croix National Scenic Riverway (NPS)
SAG	Science Advisory Group
SCWRS	Saint Croix Watershed Research Station
SDE	Spatial Database Engine
SEM	Structural Equation Models
SLBE	Sleeping Bear Dunes National Lakeshore (NPS)
SOLEC	State of the Lakes Ecosystem Conference
SOP	Standard Operating Procedures
SQL	Structured Query Language
STORET	STOrage and RETrieval
USGS	U.S. Geological Survey
VOYA	Voyageurs National Park (NPS)
WASO	Washington Support Office (NPS)
WRD	Water Resources Division (NPS)

Appendix C – Glossary of Terms

Alpha (α) is the predetermined threshold of statistical significance in null-hypothesis testing. This threshold is frequently set at 0.01, 0.05, or 0.1. *P*-values less than alpha suggest a phenomenon that would rarely occur by chance alone (e.g., a strong trend, relationship between variables, or difference between groups); tests with *P*-values greater than alpha are deemed 'non-significant.'

a priori – Beforehand; when referring to power analyses, this refers to analyses conducted prior to sampling that use existing data to obtain estimates of variability in the monitored component to either estimate sample sizes needed to detect a desired level of change or determine what amount of change can be detected with a particular sample size (see 'Power,' below).

Attributes are any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem.

Drivers are major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems.

Ecological integrity is a concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations, and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes.

Ecosystem is defined as, "a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries".

Focal resources are park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Index site is a site selected for sampling because it is of particular interest.

Indicators are a subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong. Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system (see also Vital Sign below).

Measures are the specific feature(s) used to quantify an indicator, as specified in a sampling protocol.

Power – The probability that a test will reject a false null hypothesis, or in other words that it will not make a Type II error. Power increases as sample size or effect size (e.g., magnitude of change) increases, variability in the indicator decreases, and as alpha is relaxed (= increased).

Power analysis – A calculation performed to estimate sample sizes needed to detect a desired level of change or determine what amount of change can be detected with a particular sample size. Power is a function of sample size, sample variance, effect size, and alpha; consequently, if any four of these variables are known (or chosen), the fifth can be calculated.

Probabilistic design – A sampling design in which all potential points within the sampling domain have a known probability of being selected for sampling. Selection occurs via some process that randomly selects points.

Sample panel – A group of sample units visited at the same recurring interval. Sampling units (e.g., sites) from the entire population may be subdivided into several panels, each of which may be sampled more or less frequently, depending on the re-visit strategy.

Sampling domain – The area in which samples occur. If sampling locations are randomly selected and have reasonable replication, this corresponds to the area about which inferences can be drawn.

Stressors are physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive (or deficient) level. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution.

Simple random sampling – A sampling strategy whereby the total number of sites is selected from the sampling domain such that every point has the same probability of being selected. The procedure for selecting units must be truly random.

Stratified random sampling – A sampling strategy in which the sampling domain is divided into mutually exclusive and exhaustive subpopulations called strata, each of which is clearly defined. Each sampling unit is subsequently classified into the appropriate stratum, and then a simple random sample is drawn from each stratum.

Systematic sampling – a sampling algorithm in which the first sampling unit is randomly selected and subsequent units are selected according to a regular (i.e., systematic) pattern (e.g., every *i*th grid cell) (Mendenhall et al. 1971)

Type I error –Incorrectly rejecting a null hypothesis that is actually true. For example, it is stated that a trend is detected when, in fact, none exists. When expressed as a probability, it can be symbolized by alpha (α); when expressed as a percentage, it is known as significance level.

Type II error – Failing to reject a false null hypothesis. For example, concluding that no trend (or no trend of a particular magnitude) has occurred, although one actually has.

Vital Signs, as used by the National Park Service, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).